TIMBER LAKE

C.C.C.

STUDENT HANDBOOK

INDEX

WELCOME

We welcome you to Timber Lake Job Corps. By your decision to join the Job Corps, you have taken a most important step in your personal future.

You will find life at Timber Lake very challenging, very busy and sometimes frustrating; but most of all, you will find a chance to better yourself. It will take a great deal of hard work, for we have daily chores to do and job skills to be learned. This booklet contains the basic schedules and guidelines for you to follow. Become familiar with its contents.

Our staff is here for only one purpose - to help you help yourself. Feel free to call on them to discuss any thoughts or problems you have. By working and learning together, we will succeed together.

The Job Corps program is only for those interested in bettering themselves.

If you do not cooperate and apply yourself, you will be asked to leave so that those who are willing will have a chance.

Mack Ferrick

MACK FERRICK
Center Director
Timber Lake Job Corps Civilian Conservation Center.

JOB CORPS OATH

KNOWING THAT EDUCATION AND TRAINING ARE VITAL TO MY GROWTH AND TO THE FUTURE OF OUR COUNTRY, I ACCEPT APPOINTMENT AT THE JOB CORPS AND WILL PARTICIPATE TO THE BEST OF MY ABILITY IN ALL PHASES OF THE JOB CORPS PROGRAM AND WILL COMPLY WITH ALL RULES AND REGULATIONS OF THE JOB CORPS.

MY ADDRESS IS

MR./MS.____

TIMBER LAKE CIVILIAN CONSERVATION CENTER
59868 E. HWY 224
ESTACADA, OREGON 97023

MY PHONE NUMBER IS 503-630-4291 503-834-2291

MY SOCIAL SECURITY NUMBER IS ____________________

MY HOME ADDRESS IS:

____

STREET AND NUMBER

____

CITY STATE ZIP

____

PHONE

TIMBER LAKE CIVILIAN CONSERVATION CENTER IS 53 MILES FROM PORTLAND.

ORIENTATION

ORIENTATION HAS TWO PURPOSES:

1. TO ASK QUESTIONS ABOUT YOU, SO THAT WE CAN KEEP AN UP-TO-DATE FILE FOLDER, CHECK YOUR HEALTH NEEDS, AND BE SURE YOU ARE GIVEN THE THINGS YOU NEED.
2. TO GIVE YOU INFORMATION ABOUT WHAT THE CENTER OFFERS AND TO TELL YOU WHAT IS EXPECTED OF YOU.

WE ENCOURAGE YOU TO ASK QUESTIONS AT ANY TIME AND WE WILL TRY TO HELP YOU UNDERSTAND WHAT YOU WILL NEED TO KNOW, SO THAT YOUR STAY AT TIMBER LAKE IS WORTHWHILE AND MEANINGFUL FOR YOU. ATTEND ALL REQUIRED OREINTATION MEETINGS.

RESPECT

WHEN YOU COME TO TIMBER LAKE, YOU ARE TREATED AND RESPECTED AS A PERSON. THIS RESPECT WILL CONTINUE AS LONG AS YOUR BEHAVIOR WARRANTS. IF YOU DO NOT TREAT OTHERS WITH RESPECT AND DIGNITY, THEN IT IS NOT LIKELY THAT OTHERS WILL TREAT YOU WITH RESPECT.

WE DO HAVE RULES AND THOSE WHO BREAK THE RULES ARE PUNISHED. THE RULES ARE NOT HARD TO FOLLOW AND IT IS EASY FOR YOU TO STAY OUT OF TROUBLE. LET THE RULES GUIDE THE WAY YOU LIVE AT THE TIMBER LAKE CENTER, BECAUSE THEY WERE WRITTEN TO PROTECT YOUR RIGHTS AS WELL AS THE RIGHTS OF OTHERS.

THIS PROGRAM IS DESIGNED TO INTRODUCE YOU TO THE TRADE OR TRADES OF YOUR CHOICE. THE WEEK FOLLOWING YOUR INITIAL ORIENTATION TO CENTER YOU WILL BE ASSIGNED AN O.E.P. (OCCUPATIONAL EXPLORATION PROGAM) APPOINTMENT. YOU WILL ATTEND FOR FOUR HOURS.

THIS APPOINTMENT WILL ENABLE YOU TO HAVE A "HANDS ON" EXPERIENCE WITH THE TOOLS OF THE TRADE AND TO RECEIVE INFORMATION REGARDING YOUR CHOSEN TRADE. YOU WILL NOT BE ALLOWED TO OPERATE POWER TOOLS IN THIS PARTICULAR TIME BLOCK.

WHEN YOU ATTEND O.E.P. YOU SHOULD BE DRESSED FOR WORK, STEEL TOE BOOTS, ETC. SAFETY GEAR AND INSTRUCTION WILL BE PROVIDED BY THE INSTRUCTOR. THIS TIME BLOCK IS CREATED SO THAT YOU MAY ASK QUESTIONS AND RECEIVE INFORMATION ABOUT YOUR TRADE CHOICE, SO BE PREPARED. YOU WILL BE GIVEN A PRETEST POST TEST EXAM TO DETERMINE IF A LEARNING SITUATION HAS OCCURRED. IMMEDIATELY FOLLOWING O.E.P. YOU WILL BE SCHEDULED IN TO YOUR TRADE.

IF THERE IS A WAITING LIST FOR ENTRY INTO YOUR CHOSEN TRADE YOU WILL BE ASSIGNED TEMPORARILY TO ANOTHER TRADE [illegible] YOU WILL BE SCHEDULED IN TO YOUR TRADE [illegible] AVAILABLE.

THE CENTER CAN HELP ME

GET WORK EXPERIENCE
GET A JOB
GET A DRIVER'S LICENSE
GET A GED
LEARN SKILLS
LEARN ABOUT MYSELF
LEARN ABOUT OTHERS
LEARN ABOUT CONSERVATION
IMPROVE MY TEETH
IMPROVE MY HEALTH
AND MANY MORE

I CAN HELP MYSELF BY

- KEEPING ALERT ON THE JOB
- OBEYING THE RULES AND REGULATIONS
- BEING THOUGHTFUL OF OTHERS
- USING "FREE" TIME WISELY
- DEVELOPING GOOD ATTITUDES
- BEING ON TIME
- DEVELOPING GOOD WORK HABITS
- DOING MY BEST IN EVERYTHING
- PLANNING AHEAD
- NOT LENDING OR BORROWING PERSONAL ITEMS

WEEKLY SCHEDULE

	0600	RISE
	0615	DORM CLEAN UP BEGINS
	0630	BREAKFAST
0630 -	0730	SICK CALL DISPENSARY
	0730	REPORT TO ASSIGNED AREA
1130 -	1215	EDUCATIONAL TRAINEES LUNCH
1200 -	1245	VOCATIONAL TRAINEES LUNCH
	1715	DINNER
	1800	RECREATION AND SPORTS
	2130	PREPARE FOR LIGHTS OUT
	2200	LIGHTS OUT, TV'S AND RADIOS OFF

SATURDAY SCHEDULE

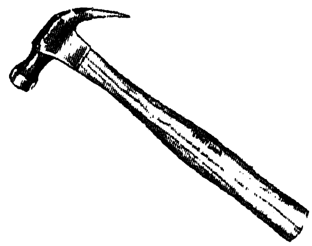
0900 - 1100	BRUNCH AT THE DINING HALL
0900 - 1100	DORM CLEAN UP
1000	BUSES LEAVING CENTER
1000 - 1800	RECREATIONAL ACTIVITIES
1300 - 1700	AFTERNOON MEAL AT DINING HALL
2300	PREPARE FOR LIGHTS OUT

SUNDAY SCHEDULE

0900 - 1100	BRUNCH AT THE DINING HALL
1000 - 1800	ANY OFF CENTER TRIPS THAT MAY BE SCHEDULED
1600 - 1700	DINNER AT THE DINING HALL
2100	DORM CLEAN-UP PREPARE FOR LIGHTS OUT
2200	LIGHTS OUT

VOCATIONAL OFFERINGS AT TIMBER LAKE

1. COOKING
2. CEMENT MASONRY--UNION PROGRAM
3. PLASTERING-UNION PROGRAM
4. CARPENTRY-UNION PROGRAM
5. FORESTRY
6. WELDING
7. BUILDING MAINTENANCE
8. PAINTING-UNION PROGRAM



WORK HARD AND LEARN ALL YOU CAN WHILE YOU ARE AT

TIMBER LAKE

YOUR JOB MAY DEPEND ON IT

CULINARY ARTS PROGRAM

I. Selection Criteria

Corpsmembers are screened by the Food Service Manager to determine trainee suitability through the Occupational Exploration Program. Emphasis is placed on trainee's desires to succeed as a cook.

II. Program Expectations

Efficient work habits and personal hygiene are of the utmost importance.

III. Educational Requirements

No specific educational level is mandatory. However, a working knowledge of measurements is desirable. Every student is allowed to progress at an appropriate rate and the student must progress.

IV. Program Placement

Students who desire training in the cooking vocation can usually be placed immediately after the Occupational Exploration Program.

V. Learning Skills Offered

Learning skills offered are the following: kitchen sanitation, use of the French knife and other basic tools, operation, care and cleaning of electrical equipment, knowledge of basic food-born diseases, cooking and serving various meats and vegetables, salad and sandwich preparation, garnishing foods, beverage preparation, and, kitchen maintenance. In addition to preparing meals for the Center population, practical experience is gained by catering special events in the community. As a part of training , students will go on many educational trips through restaraunts, gallereis, and meat packing plants.

The twelve week program is designed to prepare the student for a variety of positions in commercial hotels and restaraunts. Upon satisfactory completion of the required training skills the students can quality for a completion and job placement in one of the following areas:

A. Kitchen Maintenance-starting pay ranges from minimum wage to $4.00 per hour....individual must be familiar with all phases of kitchen sanitation and know the safe and effecient use of various chemical cleaners.

B. Pantry Person - starting pay ranges from minimum wage to $4.50 per hour...job duties are preparing dressings, salads, cold sandwiches

and deserts;

C. Short Order Cook - starting pay ranges from $4.00 to $5.00 per hour...Duties Center around grill work (eg. grilled sandwiches, eggs, fries, etc.);

D. Cooks Helper - starting pay is minimum wage to $5.50 per hour... assists cooks in preparing the menu items.

VI. Length of Training

Approximately twelve months depending on the skill level of the trainee.

VII. Program Completion

Completion is determined by the Food Service Manager and is based on all around development of Corpsmembers in the Culinary Arts or food service field.

VIII. Employment Opportunities

The graduate of our school leaves better prepared to enter the American Culinary Federation Apprenticeship Program because the texts and tests are the same. Placement opportunities are excellent. Food service is the second largest industry in the United States. Tranfers to local community colleges and to the National Maritime Union Training Center at Treasure Island, near San Francisco, for advanced career training are available to those who qualify academically.

IX. Wages and Working Hours

Hourly wages range from minimum to $5.50 perhour, for entry level positions. Work week consists of forty hours. Employees may be required to work a variety of shifts, week-ends, and/or holidays.

UNION CEMENT MASONRY PROGRAM

I. Selection Criteria

Trainees are selected through the Occupational Exploration Program. Corpsmembers must demonstrate an overall willingness to become a mason. Corpsmembers must be seventeen years of age. Selection is generally on a first-come,first-serve basis. However, a serious attitude and willingness to learn the trade must be evidenced.

II. Program Expectations

Students entering the program should be in top physical condition due to the heavy work required. They will climb scaffolds, carry heavy loads, and spend many hours on their knees troweling floors. Dexterity and coordination are needed as well as a desire to do the work. While the student is here they are expected to maintain a good personal appearance and to relate well with peers. They must be punctual and have good work habits.

III. Educational Requirements

To enter the program students will need a good understanding of math and should be able to compute with fractions. The ability to read a rule and measuring tape will be necessary. No specific educational level attainments are required. However, an interest and a reasonable aptitude must exsist. What needs to be learned can be gained after entry into the program. We strongly recommend each corpsmember work towards a G.E.D.

IV. Program Placement

Corpsmembers can usually be placed in the program as soon as they demonstrate competency regarding required learning skills through the Occupational Exploration Program.

V. Learning Skills Offered

Students will learn rough carpentry skills from building forms for walks, floors, steps and curbs. They will also learn to mix concrete as well as flat work and also install some reinforcing steel. The program will consist of classroom, shopwork and blueprint reading.

VI. Program Completion

Determined by the Coordinator, along with the instructors and is based on all-around development to the point of being truly employable in the trade as an apprentice. Key factors including maturity, dependability, punctuality, and work habits as well as the basic skills of the trade.

VII. Length of Training

The minimum of eight months to accomplish these goals listed above.

VIII. Employment Opportunities

Opportunities for program completers are greatly enhanced as these individuals are in a much better position to compete for jobs available in the industry.

IX. Wages and Working Hours

Working hours are usually eight hours per day, five days per week. Apprenticeship trainees receive a percentage of journeyman pay.

UNION PLASTERING PROGRAM

I. Selection Criteria

Students must be seventeen years of age or older and express a desire to enter and complete the plastering trade. Each individual must be able to comprehend and retain the material in the first-year apprenticeship books. Selection occurs through the Occupational Exploration Program and a serious attitude and willingness to learn the trade must be evidenced.

II. Program Expectations

Students are expected to be self-motivated and physically able to accomplish heavy work.

III. Educational Requirements

A good basic Education is necessary. No specific educational level attainments are required; however, an interest in learning and a reasonable aptitude must exsist. What needs to be learned can be gained after entry into the program. We strongly recommend each corpsmember work toward a G.E.D.

IV. Program Placement

Corpsmembers are usually placed in the program upon demonstration or required skill areas through the Occupational Exploration Program.

V. Learning Skills Offered

Learning skills include all basic and interior and exterior materials and their use; work with all trade tools on training projects and use of textbooks of the trade.

VI. Program Completion

Students can expect to complete in fifty-two weeks.

VII. Employment Opportunities

Placement opportunities are usually good in most areas of the United States depending on the state of the economy.

VIII. Wages and Working Hours

When placed as an apprentice, the wage is usually fifty percent of the prevailing scale for each geographic area. Working hours are usually five days a week, eight hours a day.

UNION CARPENTRY PROGRAM

I. Selection Criteria

Students are screened by the Coordinator, during the Occupational Exploration Program, to see that they meet minimum requirements and that no illness or handicap exsists that could be dangerous to the trainee or co-worker. Selection is generally on a first-come, first-serve basis. However, a serious attitude and willingness to learn the trade must be evidenced.

II. Program Expectations

Students MUST progress satisfactorily in ALL areas on Center:

A. Obey Center rules and function successfully in group living.

B. Progress at a reasonable rate in Education.

C. Progress at a reasonable rate in Carpentry skills and work habits required by employers to be employable as a beginning apprentice.

D. Pass the National Joint Qualifying Exam for entry into the Apprenticeship Carpentry.

III. Educational Requirements

Reading Level: the student must be able to write legibly and read and comprehend basic textbooks. Math level: students must be able to understand the need for math as a tool of the trade and be willing to increase skills.

IV. Program Placement

Corpsmembers can usually be placed in the program as soon as they have demonstrated the skills required through the Occupational Exploration Program.

V. Learning Skills Offered

All the basic manipulative skills to SAFELY function as a first-year apprentice: carpentry terminology, nomenclature of tools and materials, care and use of hand tools and powere equipment, actual experience layout, footing forms, wall forms, column forms, wall framing (metal and wood, drywall installation, door hanging, and other miscellaneous tasks).

VI. Program Completion

This program is Union supervised. At the end of a twelve month period, a student can expect to be placed with an employer as an apprentice for a two-year apprenticeship. Pay starts at fifty percent of the journeyman's scale. Raises occur with progression towards completion.

VII. Length of Training

Duration of training is approximately one year. In special cases, trainees may remain for a longer period of time.

VIII. Employment Opportunities

Employment opportunities are variable depending on the state of the economy.

IX. Wages and Working Hours

The work week consists of forty hours. Apprenticeship trainees receive a percentage of journeyman pay (determined by prevailing rate).

FORESTRY PROGRAM

I. Selection Criteria

Students who desire Forestry will be placed through the Occupational Exploration Program.

II. Program Expectations

Students are expected to work outside year-round, to report to work on time, follow instructions, and to show a serious attitude and a willingness to learn the trade.

III. Educational Requirements

Educational requirements consist of the following: a good understanding of mathematics and reading is desirable but not required. We encourage all Corpsmembers to work towards a G.E.D.

IV. Program Placement

All corpsmembers will be placed as space becomes available.

V. Learning Skills Offered

The following are included" tree planting and timber stand improvement, campground maintenance, logging systems, timber cruising and outdoor survival, and, for students eighteen and over, fire behavior, use, and control.

VI. Program Completion

A minimum of 800 hours of vocational training is required to complete the course. The maximum provided is 1000 hours.

VII. Length of Training

Generally 800 to 1000 hours or approximately ten months.

VIII. Employment Opportunities

Varied - many seasonal jobs with the Forest Service are available. Currently placement and career opportunities for minority students are very good with the Federal Government. At present, opportunities in the Timber Industry are being explored.

IX. Wages and Working Hours

Work week consists of forty hours with some exceptions, such as fire season. Salaries range from $3.83 to $6.00 per hour for entry level positions.

WELDING PROGRAM

I. Selection Criteria

Selection is generally on a first-come, first serve basis and occurs through the Occupational Exploration Program. A serious attitude and willingness to learn the trade must be evidenced.

II. Program Expectations

Students must progress in all required areas on Center, must show sincere interest in becoming a welder, must demonstrate that he/she can follow instruction and work safely, and must not have a serious handicap that would impair ability to perform in this occupational area.

III. Educational Requirements

No specific educational attainments are required. However, an interest in learning and a reasonable aptitude must exsist. What needs to be learned can be gained after entry into the program. We strongly recommend that each corpsmember work towards the G.E.D.

IV. Program Placement

Corpsmember will usually be placed in the program when space is available.

V. Learning Skills Offered

These consist of the following: a proficiency in arc welding (all positions. 60-11, 6013, and 7018 electrode, 7024 electrode, all position MIG, and steel and aluminum TIG, gas welding, torch cutting and fabrication, blueprint reading, measuring including addition and subtraction of fractions and conversion to decimals.

VI. Program Completion

Determined when the trainee has adequately mastered the required vocational skills.

VII. Length of Training

The minimum length of training is 600 to 800 hours for completion.

VIII. Employment Opportunities

Placement opportunities are good depending on geographical location.

IX. Wages and Working Hours

Working hours are usually eight per day, five days per week. Wages range from $6.00 to $9.00 per hour.

BUILDING MAINTENANCE PROGRAM

I. Selection Criteria

Selection will occur through the Occupational Exploration Program. The trainee must be physically capable of meeting the following standards:

A. able to lift fifty lbs, carry twenty five lbs.

B. able to climb, walk and stand maintaining body equilibrium.

C. use fingers, hands, arms and back muscles.

D. work inside and out.

E. must have good hand/eye coordination.

II. Program Expectations

A. Student must be willing to spend twelve to sixteen months learning building maintenance.

B. must be willing to work at disagreeable and dirty tasks such as those associated with plumbing, painting, working under buildings, etc.

C. must be willing to work, study, and cooperate as a member of a crew and follow instructions correctly.

D. able to learn by text and shop work.

III. Educational Requirements

The student must be willing to attend school and improve any educational deficiency evidenced since a fair knowledge of math and english are essential in acquiring tool skills, learning maintenance procedures, and comprehending technical manuals. Completion of constructual building maintenance does not require a G.E.D., but it is advisable if a student wishes to advance to supervisory levels. A good knowledge of math is expected upon completion.

IV. Program Placement

Students will be placed as space becomes available.

V. Learning Skills Offered

Use of basic tools and procedures associated with general building maintenance and repairs; installation work involving carpentry, electrical repairs, plumbing, window glass, appliance repair, painting, metal work, etc. Troubleshooting techniques are also included.

VI. Program Completion

Approximately 1600 hours are required for completion of the program: 800 hours of general maintenance instruction (electrical and plumbing) and 800 hours of carpentry-oriented maintenance procedures and tool use. A schedule of fifty percent work and fifty percent education usually requires sixteen months for completion of the program. A student in full-time vocation can complete in a shorter time. The total time required can be pared down by a motivated and capable student.

VII. Length of Training

Length of training ranges from 1400 to 1600 hours.

VIII. Employment Opportunities

Includes private enterprises such as large stores, commercial buildings, warehouses, shipyards, and various city, county, state, and Federal government agencies.

IX. Wages and Working Hours

Normal work week consists of forty hours per week. Wages range from $3.80 to $6.00 per hour for entry level positions.

UNION PAINTING PROGRAM

I. Selection Criteria

Students must be seventeen years of age or older and express a desire to enter and complete the painting trade. Each individual must be able to comprehend and retain the material in the first-year apprenticeship books, not be color blind and have no fear of heights. Selection is generally on a first-come, first-serve basis and occurs through the Occupational Exploration Program. A serious attitude and willingness to learn a trade must be evidenced.

II. Program Expectations

Trainees must demonstrate the following: ability to follow instructions, work safely, work and live in harmony with others.

III. Educational Requirements

Educational requirements consist of the following: a good understanding of addition, subtraction, multiplication and division. A good working knowledge of fractions. Strongly recommend a G.E.D.

IV. Program Placement

Corpsmembers can usually be placed in the program as soon as they have demonstrated the required skills through the Occupational Exploration Program.

V. Learning Skills Offered

All phases of painting plus dry wall taping, wall and floor covering.

VI. Program Completion

The program is Union supervised. Students are expected to complete the training in one year or when skills are adequate to succeed as an apprentice.

VII. Length of Training

Approximately 1000 hours are required for completion of the program.

VIII. Employment Opportunities

Employment Opportunities are usually excellent depending on the economy.

IX. Wages and Working Hours

Work week constitutes forty hours. Apprenticeship trainees receive a percentage of journeyman pay, determined by prevailing rates.

TIMBER LAKE CIVILIAN CONSERVATION CENTER WAS ACCREDITED BY THE NORTEST ASSOCIATION OF SECONDARY SCHOOLS IN 1971. THE STAFF AND EDUCATION DEPARTMENT IS DEDICATED TO TEACHING TIMBER LAKE STUDENTS THE SKILLS THEY NEED TO EARN A G.E.D., AS WELL AS ENRICHMENT OFFERINGS IN A WIDE VARIETY OF SPECIALIZED AREAS.

DO I HAVE TO GO TO SCHOOL? YES. IF YOU DO NOT HAVE A G.E.D. OR DIPLOMA, YOU WILL BE GIVEN TESTS AND PREPARATION IN READING, SOCIAL STUDIES, ENGLISH, AND SCIENCE. IF YOU HAVE A HIGH SCHOOL DIPLOMA OR A G.E.D., YOU NEED TO SHOW COMPETENCY IN MATH AND READING BEFORE COMPLETING EDUCATION.

WHAT TESTS DO I TAKE? YOU WILL TAKE A SERIES OF WRITTEN TESTS TO DETERMINE YOUR EDUCATIONAL ACHIEVEMENT SO THAT WE CAN PUT YOU IN THE PROGRAM THAT WILL BEST HELP YOU. FROM THESE TESTS, WE DETERMINE WHAT YOU NEED HELP IN AND HOW WE CAN BEST HELP YOU. IT IS IMPORTANT TO DO YOUR BEST IN ALL THESE TESTS.

HOW LONG DOES IT TAKE TO GET A G.E.D.? THE ONLY TIME LIMIT IS YOUR ABILITY AND THE AMOUNT OF EFFORT YOU PUT FORTH.

THE EDUCATION DEPARTMENT OFFERS A NUMBER OF WORTHWHILE EXPERIENCES IN ADDITION TO G.E.D. PREPARATION:

AN INDEPENDENT LEARNING CENTER IS UNDER DEVELOPMENT FOR YOUR SPECIAL NEEDS AND INTERESTS. THE LEARNING CENTER OFFERS A WIDE VARIETY OF

AUDIO-VISUAL MATERIALS, PAPERBACK BOOKS, AND REFERENCE MATERIALS, ALL FOR YOUR USE AND ENJOYMENT.

DRIVER'S TRAINING IS AVAILABLE IF YOU WOULD LIKE A LICENSE OR IF YOU NEED ONE TO CERTIFY IN A TRADE.

HEALTH IS TAUGHT TO GIVE YOU VALUABLE INFORMATION ABOUT YOURSELF AND YOUR BODY, AND FIRST AID IS OFFERED IF YOU WANT TO LEARN SOME SKILLS THAT COULD ONE DAY SAVE A LIFE.

WORLD OF WORK TEACHES YOU SKILLS ON HOW TO FIND AND KEEP A JOB. YOUR FINAL PROJECT IN THIS COURSE IS AN EXPERTLY PREPARED RESUME, WHICH COULD BE A KEY TO GETTING A JOB.

PHYSICAL EDUCATION IS OFFERED TO HELP YOU GET IN SHAPE AND LEARN SOME LIFETIME RECREATION SKILLS.

IF YOU WOULD LIKE TO LEARN ABOUT WRITING, YOU CAN WORK ON THE CENTER NEWSPAPER OR CONTRIBUTE TO THE CREATIVE WRITING MAGAZINE.

A COMPUTER IS AVAILABLE TO GIVE YOU THE OPPORTUNITY TO LEARN FUNDAMENTAL CONCEPTS IN PROGRAMING, AS WELL AS TO DEVELOP SKILLS IN A VARIETY OF SUBJECTS.

THE ABOVE OFFERINGS ARE ONLY THE BEGINNING. WE ARE ALSO WORKING ON PLANS FOR A SCIENCE LAB AND A DARKROOM FOR DEVELOPING PHOTOS. WE'RE ALWAYS LOOKING FOR NEW IDEAS ABOUT SUBJECTS YOU WANT TO LEARN MORE ABOUT.

RULES AND RESPONSIBILITIES IN EDUCATION:

* SMOKING AND EATING PERMITTED IN OUTSIDE AREAS ONLY.

* RADIOS AND WALKMANS, ETC. SHOULD BE SAFELY LOCKED IN THE DORM.

* SHOW RESPECT TO ALL CORPSMEMBERS AND STAFF BY USING THE APPROPRIATE LANGUAGE AND BEHAVIOR.

* SHOW PRIDE IN EDUCATION BUILDING AND ITS SURROUNDING AREAS. KEEP THEM CLEAN.

* BE ON TIME TO EVERY CLASS.

* SLEEP IN YOUR BUNK, NOT AT YOUR DESK.

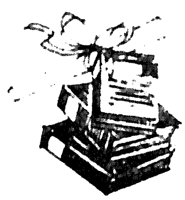
* SOCIALIZE DURING BREAKS, NOT DURING CLASS. A QUIET ROOM IS A MUST FOR LEARNING.

* SET GOALS. WORK TO YOUR FULL POTENTIAL EVERY DAY.

YOU CAN SUCCEED IN EDUCATION. THE STAFF, TUTORS, AND RESOURCES ARE HERE. YOU NEED ONLY TAKE RESPONSIBILITY FOR YOUR PROGRAM AND BE COMMITTED TO YOUR GOALS.

GOOD LUCK!

THE EDUCATION STAFF



LIVING ALLOWANCES

DURING THE FIRST 60 DAYS (2months) CORPSMEMBERS ARE ENTITLED TO AN INITIAL REGULAR MONTHLY LIVING ALLOWANCE OR $40.00 PER MONTH.

AT THE END OF 90 DAYS (3 months) THE CORPSMEMBER WILL RECEIVE AN AUTOMATIC INCREASE TO $60.00 PER MONTH. (UNLESS FOR SOME REASON A DELAY IS REQUESTED BY THE CENTER DIRECTOR).

AT THE END OF 180 DAYS (6months) THE CORPSMEMBER WILL RECEIVE AN AUTOMATIC INCREASE TO $80.00 PER MONTH.

ADDITIONALLY, A CORPSMEMBER AT THE $80.00 LEVEL MAY EARN MERIT INCREASES TO A MAXIMUM OF $100.00 PER MONTH TOTAL ALLOWANCES.

§ 97a.112 Limitation on political activities.

(a) No officer or employee of the Job Corps shall make any inquiry concerning the political affiliation or beliefs of any corpsmember or applicant for enrollment.

(b) No officer, employee, or corpsmember shall take any active part in political management or campaigns, except as may be provided by or pursuant to statute, and no such person shall use his official position or influence for the purpose of interfering with an election or affecting the result thereof.

(c) No program under this part shall involve political activities, and neither the programs nor the funds provided therefor, nor the personnel thereof, shall be in any way engaged in the conduct of political activities in contravention of 5 U.C. Chapter 15 (section 418 (a) and (b)).

(d) No officer, employee, corpsmember or other Federal employee shall solicit funds for political purposes from corpsmembers in contravention of 18 U.S.C. 602

GOVERNMENT AND YOU

1. TO PROTECT YOUR RIGHTS AS AN AMERICAN CITIZEN AND A PROUD MEMBER OF TIMBER LAKE CIVILIAN CONSERVATION CENTER, THE STAFF WANT YOU TO KNOW THAT:

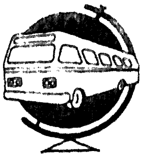
LOCAL,
STATE, AND
FEDERAL LAWS APPLY TO YOU WHILE YOU ARE ON CENTER OR ON A CENTER SPONSORED TRIP OR ACTIVITY AWAY FROM THE CENTER.

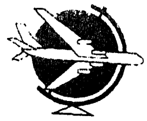
YOU WILL BE EXPECTED TO:

A. OBEY THE LAW
B. RESPECT THE RIGHTS OF OTHERS
C. MAINTAIN PRIDE IN APPEARANCE; BE CLEAN AND WELL GROOMED
D. KEEP DUTY HOURS
E. FOLLOW LEAVE REGULATIONS
F. CARE FOR CENTER PROPERTY
G. KEEP APPOINTMENTS AND SCHEDULES

NOTICE

FOR A COMPLETE UNDERSTANDING OF THE CENTER'S DISCIPLINE PROGRAM INCLUDING MAJOR AND MINOR OFFENSES AS WELL AS YOUR RIGHTS AS A STUDENT ON THIS CENTER REFER TO THE PART OF THIS HANDBOOK CALLED DISCIPLINE AND INCENTIVES.





HOME LEAVE

IS EARNED AT THE RATE OF TWO DAYS A MONTH FROM THE DATE THAT I AM ENROLLED IN THE JOB CORPS.

MAY BE TAKEN AFTER I HAVE BEEN IN THE JOB CORPS FOR SIX MONTHS.

MUST MEET THE APPROVAL OF THE CENTER DIRECTOR.

MAY BE TAKEN ONCE DURING THE FISCAL YEAR (BEGINNING JULY 1 AND ENDING JUNE 30).

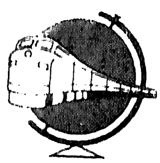
EMERGENCY LEAVE

MUST MEET THE APPROVAL OF THE CENTER DIRECTOR.

EMERGENCY LEAVE IS NOT CHARGED TO REGULAR LEAVE TIME. HOWEVER, THE TRANSPORTATION PROVIDED DOES CONSTITUTE ONE GOVERMENT PAID LEAVE.

MAY BE GIVEN IF DEATH OR SERIOUS ILLNESS OCCURS IN THE IMMEDIATE FAMILY; THIS MUST BE VERIFIED BY THE AMERICAN RED CROSS.

EMERGENCY LEAVE CAN BE TAKEN FOR TWELVE DAYS ONLY.



FOR YOUR MAXIMUM BENEFIT - WE'VE GOT P/PEP

P/PEP STANDS FOR PROGRESS AND PERFORMANCE EVALUATION PANEL. ONE OF THE FEATURES OF THIS PROGRAM IS THAT YOU WILL BE TREATED AS AN INDIVIDUAL INSTEAD OF GROUPING INDIVIDUALS TOGETHER. IN ALL CASES, YOUR PROGRESS AND PERFORMANCE IN THE PROGRAM IS BEING EVALUATED BY THE PANEL ON A REGULAR BASIS, AND YOU ARE BEING DEALT WITH AS AN INDIVIDUAL ACCORDING TO YOUR PROGRESS AND PERFORMANCE.

EACH STUDENT WILL BE ENCOURAGED TO COMPLETE AS MUCH OF THE OCCUPATIONAL, SOCIAL ATTITUDINAL, EDUCATIONAL AND COMMUNICATIONS SKILLS PROGRAMS AS ABILITIES WILL ALLOW. WHEN THE PANEL DETERMINES, THROUGH EVALUATION AND PERSONAL INTERVIEW, THAT YOU HAVE RECEIVED THE MAXIMUM BENEFITS FROM ANY PROGRAM AREA, YOU ARE TO BE CONSIDERED AS HAVING MET THE MINIMUM PROGRAM COMPLETION REQUIREMENTS OF THE EDUCATIONAL, GROUP LIVING AND OCCUPATIONAL PROGRAMS.

THIS PANEL WILL CONSIST OF SOMEONE FROM THE EDUCATION DEPARTMENT, YOUR VOCATIONAL INSTRUCTOR AND YOU GROUP LEADER. THEY WILL MEET WITH YOU ON A REGULAR BASIS AND DISCUSS HOW YOU ARE DOING ON THIS CENTER.

GROUP LIVING

GENERAL AND SPECIFIC OBJECTIVES: THE GOAL OF THE GROUP LIVING PROGRAM IS TO PROVIDE THE CONDITIONS WHICH ENCOURAGE AND FACILITATE EACH STUDENT TO:

1. DEVELOP A SELF-CONCEPT WHICH IS ACCEPTABLE TO THEMSELVES AND OTHERS.

2. RESPECT THE NEEDS OF OTHERS BY ADOPTING BEHAVIOR WITHIN THE RANGE ACCEPTABLE TO SOCIETY.

3. RECOGNIZE TOTAL RESPONSIBILITY AS A TIMBER LAKE STUDENT AND CONTRIBUTE TO THE COMMON GOOD.

SPECIFIC OBJECTIVES:

1. TAKING CARE OF THE DORM AREA, CLOTHING AND SUPPLIES, AND BY MANAGING A LIVING ALLOWANCE SO AS NOT TO INCUR FREQUENT OR UNREASONABLE DEBT.

2. EXHIBITING ACCEPTABLE PERSONAL APPEARANCE, BODY CARE, SPEECH, AND MANNERS.

3. ATTENDING ON TIME, SCHEDULED CENTER AND DORMITORY ACTIVITIES, AND LETTING SOMEONE KNOW WHEN THEY CAN'T ATTEND.

4. RESPECTING THE LAW AND THE RIGHTS OF OTHERS AND CENTER RULES AND REGULATIONS.

5. HELPING OTHERS TO DEVELOP TASK OR SOCIAL SKILLS BY WORKING EFFECTIVELY IN GROUP EXERCISES AND PARTICIPATING IN STUDENT GOVERNMENT, CENTER, OR COMMUNITY RELATIONS PROJECTS.

THE GROUP LIVING PROGRAM WILL PROVIDE A CLEAN, SECURE, LIVING AREA AND VARIED LEISURE TIME ACTIVITIES THAT WILL PROMOTE THE PERSONAL-SOCIAL DEVELOPMENT OF STUDENTS.

EACH DORM HAS SPECIALIZED STAFF MEMBERS TO HELP EVERY STUDENT. STUDENT LEADERS ARE ALSO USED IN THE MANAGEMENT OF THE DORMS.

EVERY STUDENT IS RESPONSIBLE FOR THEIR OWN AREA AND WILL COOPERATE WITH OTHERS IN KEEPING THE DORM CLEAN.

THE OLD SAYING "LEADERS ARE BORN, NOT MADE" IS UNNACCEPTABLE TO TIMBER LAKE STAFF AND STUDENTS. THE OVERALL PHILOSOPHY IS ONE OF INDIVIDUAL GROWTH AND DEVELOPMENT OF SKILLS, TO BECOME AN INVOLVED CITIZEN IN THE TIMBER LAKE COMMUNITY.

THREE VERY MEANINGFUL PROGRAMS ARE OFFERED AT TIMBER LAKE IN DEMOCRATIC LEADERSHIP DEVELOPMENT. THESE ARE STUDENT COUNCIL, STUDENT LEADERSHIP TRAINING AND UNITED STATES JAYCEES. THESE ARE ALL VOLUNTARY SERVICE PROGRAMS WHICH OFFER A WIDE VARIETY OF EXPERIENCE IN BOTH INDIVIDUAL AND GROUP DECISION MAKING.

THE STUDENT COUNCIL IS MADE UP OF STUDENTS AND STAFF ON CENTER. MEMBERS ARE VOTED IN BY FELLOW STUDENTS IN CENTER WIDE ELECTIONS. THE PURPOSE OF THE COUNCIL IS (1) TO MAKE RECOMMENDATIONS TO THE CENTER DIRECTOR FOR IMPROVEMENT OF CENTER OPERATIONS TO BENEFIT THE STUDENT POPULATION. (2) ACT AS A COMMUNICATIONS CHANNEL BETWEEN THE CENTER DIRECTOR AND THE STUDENT POPULATION. (3) MAKE RECOMMENDATIONS TO THE CENTER DIRECTOR FOR THE EXPENDITURES OF FUNDS DERIVED FROM THE OPERATION OF THE STUDENT COMMISSARY, DISCIPLINARY FINES AND OTHER FUND RAISING ACTIVITIES. FUNDS MAY ONLY BE USED TO OPERATE ACTIVITIES OR MAKE PURCHASES OR LOANS WHICH CLEARLY BENEFIT THE STUDENT POPULATION.

STUDENT LEADERSHIP TRAINING

THE LEADERSHIP PROGRAM EXSISTS TO DEVELOP RESPONSIBILITY AND LEADERSHIP ON THIS CENTER. LEADERSHIP TRAINING OCCURS 4 TIMES A YEAR AND, IF CHOSEN FOR STUDENT LEADERSHIP, YOU WILL BE REQUIRED TO ATTEND THE TWO DAY TRAINING WORKSHOP. THERE IS A SEVEN POINT SYSTEM THAT THE LEADERSHIP PROGRAM WILL ENCOURAGE:

1. MAXIMUM PARTICIPATION OF STUDENTS IN RESPONSIBLE ROLES RELATED TO ALL ASPECTS OF CENTER LIFE.
2. DEVELOPMENT OF LEADERSHIP SKILLS IN WORKING WITHIN ORGANIZATIONAL STRUCTURES.
3. CLEAR CHANNELS OF COMMUNICATION TO AND FROM STUDENTS.
4. MEANS OF HANDLING GRIEVANCES FAIRLY.
5. HABITS OF COOPERATION IN GROUP EFFORTS.
6. GOOD CITIZENSHIP AND TRAINING FOR SELF MANAGEMENT.
7. SUPPLEMENTATION OF AVAILABLE STAFF CAPACITIES BY UTILIZING THE SKILLS OF STUDENTS TO SUPERVISE AND TRAIN OTHERS.

THE CENTER"S AIM IS TO DEVELOP THE SEVEN POINT SYSTEM SO THAT EACH INDIVIDUAL LEADER WILL PARTICIPATE AND PRACTICE THE SYSTEM WITH A DEGREE OF EFFICIENCY THAT WILL BE REWARDING TO THE CENTER AND TO THE INDIVIDUAL.

THE RESIDENTIAL LIVING MANUAL STATES: "PARTICIPATION OF THE CORPS-MEMBERS IN DECISION MAKING AND LEADERSHIP ON THE CENTER IS ESSENTIAL FOR OPTIMAL CENTER OPERATION. CORPSMEMBERS WHO FEEL THAT THEY SHARE THE RESPONSIBILITY FOR CENTER OPERATIONS, THAT THEIR NEEDS AND OPINIONS ARE RECEIVING CONSIDERATION, AND THAT THEY ARE PARTNERS IN A JOINT JOB CORPS ENTERPRISE ARE MOST LIKELY TO PUT FORTH THEIR BEST EFFORTS TO MAKE A SUCCESS OF THE CENTER. WHEN YOUNG PEOPLE DO NOT GET A CHANCE TO PARTICIPATE IN GOVERNMENTAL PROCESS, THEY TEND TO REJECT THE ACTIVITIES OR RULINGS THAT THE GOVERNING BODY PROMOTES."

UNITED STATES JAYCEES

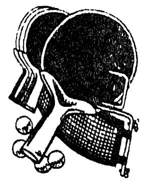
THE JAYCEE ORGANIZATION HAS A FUNDAMENTAL IDEA THAT YOUNG PEOPLE CAN BECOME INVOLVED IN PUBLIS SERVICE. BEING YOUTHFUL IS NOT A HANDICAP IN THE PARTICIPATION OF COMMUNITY, STATE AND NATIONAL ISSUES.

THE TIMBER LAKE JAYCEE CHAPTER ENCOURAGES NEW STUDENTS TO JOIN IN THEIR ORGANIZATION. ACTIVITIES INCLUDE COMMUNITY ACTION PROGRAM, INDIVIDUAL DEVELOPMENT AND CHAPTER LEADERSHIP PROJECTS AND A VARIETY OF SOCIAL ACTIVITIES.

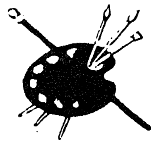
GET INVOLVED IN YOUR NEW COMMUNITY OF TIMBER LAKE. JOIN ONE OF THESE ORGANIZATIONS FOR PERSONAL AND CENTER BETTERMENT.

ONE OF THE BIGGEST CHALLENGES FOR YOU AS AN INDIVIDUAL IS USING YOU "FREE" TIME WISELY. DON'T KILL TIME WHILE AT TIMBER LAKE. MAKE IT LIVE FOR YOU AND OTHERS.

JOIN IN WITH YOUR FELLOW STUDENTS BY SERVING ON THE COUNCIL, AS A STUDENT LEADER OR IN THE JAYCEES.



RECREATION



TIMBER LAKE HAS AN EXCELLENT RECREATION PROGRAM. WE HAVE MANY SPORTS ACTIVITIES, ARTS AND CRAFTS, GAMES, MOVIES, ETC. WE HAVE A BRAND NEW GYMNASIUM AND YOU WILL BE REQUIRED TO WEAR TENNIS SHOES IN THE GYM AREA. THESE WILL BE PROVIDED TO YOU BY THE CENTER.

THE CENTER HAS OFF CENTER ACTIVITIES AS WELL AS ON CENTER ACTIVITIES. YOU WILL GO TO VARIOUS RECREATIONAL FUNCTIONS IN PORTLAND AND SURROUNDING AREAS. YOU MAY ATTEND CONCERTS, SPORTS EVENTS SUCH AS BOXING (WE HAVE A GREAT BOXING PROGRAM), FOOTBALL, BASEBALL, BASKETBALL, HOCKEY, SKATING, DANCES, ETC. ADMISSION TO MANY OF THESE EVENTS ARE AT REDUCED RATES THROUGH THE RECREATION COUNCIL.

THE LIST BELOW WILL GIVE YOU AN IDEA OF THE MANY THINGS THAT ARE OFFERED THROUGH THE CENTER.

BASKETBALL	VOLLEYBALL	POOL
FLAG FOOTBALL	CHURCH SERVICES	TABLE TENNIS
BASEBALL	CERAMICS	MOVIES
SOFTBALL	CAMPING	ARCHERY
INTRAMURALS	FISHING	HIKING
WEIGHT LIFTING	SWIMMING	ROLLER SKATING
SMALL GAMES	HORSESHOES	MUSIC

SWIMMING IS UNDER STAFF SUPERVISION ONLY. DO NOT GO NEAR THE WATER OTHERWISE. YOU ARE REQUIRED TO BECOME INVOLVED IN THE CENTER DROWNPROOFING PROGRAM OFFERED BY THE RECREATION DEPARTMENT.

Equal Employment Opportunity
(E.E.O.)

Equal Emploment Opportunity System:

E.E.O. Counselors are on the Forest to Assist with complaints on any issue where an individual feels that they have been unfairly dealt with. The Forest Service has about 320 E.E.O. Counselors scattered throughout the country. Approximately 70 in this region and 7 on the Mt. Hood National Forest.

Any student at Timber Lake that believes that they have been harmed by a discriminatory action or decision must consult with an E.E.O. Counselor concerning the issue before filing an E.E.O. complaint. The E.E.O. Counselor representing the student population at Timber Lake is the Occupational Exploration Instructor. The counselor must be contacted within 30 days of an alleged discriminatory action or within 30 days of learning of such an action. The Counselor is not an advocate or representative of the compainant nor of the Forest Service. The counselor is trained to seek fair solutions, to valid complaints, by communicating with Forest Service officials, facilitating settlements and discussing issues with the complainant. If within 21 days the issue is not settled, the complainant can file an official formal complaint. There is an E.E.O. Committee established at Timber Lake comprised of two E.E.O. Officers, one Center Federal Womens Program Representative, one Head of the Student Leadership Program and the President of the Student Council that will conduct impartial hearings on civil rights issues and handicapped complaints and will recommend desisions to the Center Director on issues brought before it. Very few complaints ever get to the formal stage as most are simply solved after discussion and open communication efforts have been employed.

Many times people wait too long to contact the counselor, do not communicate with a supervisor when a problem occurs, or do not have in mind what they want as a satisfactory solution to the situation. Remember that the 30 day limit is important. If you even think that you may want to talk to an E.E.O. Counselor concerning an issue do not hesitate to do so. Although an issue may not be of discriminatory nature, it may still be grievable through formal process.

FIRE PREVENTION

PREVENTION MEANS: TO STOP BEFORE IT STARTS.

FLAMMABLE MEANS: EASILY SET ON FIRE.

FIRE PREVENTION REGULATIONS

YOUR SAFETY IS THE REASON FOR SETTING UP FIRE PREVENTION REGULATIONS:

1. NO SMOKING IN:
   - A. BED
   - B. AUDITORIUM
   - C. EMPTY BUILDINGS
   - D. STORAGE AREAS, OR
   - E. WITHIN 50 FEET OF BULK FLAMMABLES OR EXPLOSIVES.
2. USE ASHTRAYS-DO NOT PUT:
   - A. MATCHES
   - B. CIGAR BUTTS
   - C. CIGARETTE BUTTS
   - D. PIPE CLEANINGS

   INTO WASTEBASKETS
3. EMPTY ASHTRAYS INTO WASTECANS WHICH HAVE WATER OR SAND IN THEM.
4. WASTE CANS MUST HAVE LIDS ON THEM-KEEP THE LID CLOSED. KEEP OUTDOOR WASTE CANS CLEAR OF BUILDINGS AND OVER-HANGING TREES AND SHRUBS.
5. SMOKING OUTDOORS
   STEP ON OR "FIELD STRIP" CIGARETTE OR CIGAR BUTTS.
   EMPTY PIPES ON THE BARE GROUND AND COVER HOT ASHES.
   DO NOT SMOKE IN THE WOODS OR ON HIKING TRAILS.
6. OBEY NO SMOKING SIGNS.

MEDICAL AND DENTAL HEALTH SERVICES

YOUR HEALTH IS IMPORTANT TO YOUR SUCCESS AT THE CENTER.

YOU CAN:

A. LEARN FASTER

B. WORK BETTER

C. ENJOY LIFE MORE WHEN YOU FEEL WELL

1. MEDICAL STAFF: HERE AT THE CENTER YOU HAVE:

A. TRAINED MEDICAL TECHNICIAN

B. A PHYSICIAN WHO VISITS THE CENTER ONE DAY A WEEK

C. A DENTIST

D. A DENTAL HYGIENIST

E. A MEDICAL DISPENSARY

F. A FULLY EQUIPPED AMBULANCE

2. THE DISPENSARY: LOCATED BETWEEN DORM 1 AND 2 AND THE ADMINISTRATION BUILDING. HERE YOU WILL FIND ALL MEDICAL AND DENTAL SERVICES AND REPORT FOR SICK CALL.

3. SICK CALL: THE DISPENSARY IS OPEN TO STUDENTS FOR MEDICAL OR DENTAL TREATMENT DURING THE FOLLOWING HOURS;

0630-0730

1130-1230

4. ILLNESS: IF YOU BECOME ILL DURING THE DAY YOU SHOULD CONTACT YOUR AREA SUPERVISOR, (TEACHER, VOCATIONAL INSTRUCTOR) WHO WILL ARRANGE AN APPOINTMENT FOR YOU WITH THE MEDIC.

5. EMERGENCY TREATMENT: IF YOU ARE TAKEN SUDDENLY ILL OR INJURED AT ANY TIME AFTER NORMAL DUTY HOURS (0730-1630) OR ON WEEKENDS OR HOLIDAYS CONTACT YOUR DORM COUNSELOR WHO WILL SEE THAT YOU GET IMMEDIATE MEDICAL ATTENTION.

6. AMERICAN RED CROSS FIRST AID TRAINING: DURING YOUR ENROLLEMENT AT TIMBER LAKE YOU MAY BE GIVEN THE OPPORTUNITY TO ENROLL IN THE AMERICAN RED CROSS MULTI-MEDIA FIRST AID COURSE.

7. FEDERAL EMPLOYEES COMPENSATION BENEFITS: YOU AS A STUDENT ARE CONSIDERED AS FEDERAL EMPLOYEES FOR THE PURPOSE OF FEDERAL EMPLOYEES COMPENSATION (FEC). FOR FUTURE DETAILS OF THIS PROGRAM AND ITS BENEFITS SEE YOUR COUNSELOR.

HELP YOURSELF TO GOOD HEALTH

GO TO MEALS REGULARLY

DRINK PLENTY OF WATER

KEEP YOURSELF CLEAN.....

BODY, HAIR, FINGERNAILS

COVER YOUR MOUTH AND TURN YOUR HEAD WHEN YOU COUGH

DO NOT STAY OUT IN THE SUN TO LONG.....

SUNBURN CAN BE PAINFUL AND MAKE YOU ILL

TAKE GOOD CARE OF YOUR TEETH.....

BRUSH AFTER MEALS AND SNACKS

BRUSH BEFORE GOING TO BED

DRESS PROPERLY FOR BAD WEATHER

FOLLOW RULES FOR:

WATER SAFETY

SHOP SAFETY

PEDESTRIAN SAFETY

KEEP MEDICAL AND DENTAL APPOINTMENTS

<u>WHAT DO I DO IF I GET SICK?</u> WE HAVE A COMPLETE MEDICAL FACILITY FOR YOU IN THE DISPENSARY. A STAFF MEDIC IS ON DUTY EACH WEEKDAY. YOU CAN SEE THE MEDIC ON WEEKDAYS BETWEEN 6:30 AND 7:30 AM AND BETWEEN 11:30 AND 12:30 MONDAY THROUGH FRIDAYS. EMERGENCY MEDICAL TREATMENT WILL BE HANDLED AS THE NEED ARISES. IF YOU ARE INJURED OR GET SICK DURING WORK HOURS, YOUR VOCATIONAL INSTRUCTOR OR TEACHER WILL GIVE YOU A PASS TO OBTAIN TREATMENT. IT IS YOUR RESPONSIBILITY TO KEEP ALL MEDICAL APPOINTMENTS.

<u>HOW DO I SEND MAIL?</u> A REGULAR U.S. POSTAL SERVICE LETTER BOX IS LOCATED NEAR THE DINING HALL. YOU SHOULD USE THIS BOX TO DROP YOUR LETTER IN. THE POST OFFICE PICKS UP THE MAIL DAILY, MONDAY THROUGH SATURDAY. LARGE PACHAGES AND MONEY ORDERS MAY BE SENT AND PURCHASED AT THE MAIN OFFICE; THE MAIL CLERK WILL ASSIST YOU. YOU MAY PURCHASE STAMPS AND WRITING MATERIALS AT YOUR STUDENT COMMISSARY.

<u>DO I GET ANY WORK CLOTHES?</u> YES, SHORTLY AFTER ARRIVAL YOU WILL BE ISSUED AN INITIAL SUPPLY OF WORK CLOTHING, BOOTS, JACKET, ETC.

HOW MUCH MONEY WILL I GET FOR MY PERSONAL NEEDS? FORTY ($40) PER MONTH FOR THE FIRST TWO MONTHS; $60 PER MONTH FOR THE NEXT FOUR MONTHS; AND $80 PER MONTH AFTER THAT.

CAN I GET MORE THAN $80? YES. AFTER SIX MONTHS, INCREASES TO $90 AND $100 PER MONTH MAY BE EARNED FOR OUTSTANDING PERFORMANCE.

WHEN WILL I GET MY FIRST PAYCHECK? NO LATER THAN ONE MONTH AFTER YOU ENTER. PROVISIONS ARE MADE AT THE CENTER TO ADVANCE FUNDS UNTIL YOUR FIRST CHECK ARRIVES WHICH WILL BE REPAID BY YOU IN THE AMOUNT OF THE ADVANCE.

WILL I GET ANY MONEY WHEN I LEAVE JOB CORPS TO HELP ME GET STARTED IN MY NEW LIFE AND NEW CAREER? YES. IF YOU STAY IN JOB CORPS MORE THAN SIX MONTHS.

HOW MUCH WILL I GET? IF YOU STAY MORE THAN 6 MONTHS, YOU WILL GET $450.00.

7 MONTHS YOU WILL GET $550
8........................ 660
9...................... 750
10....................1,000
11....................1,100
12....................1,200
12 +...ADD $100 EACH MONTH

IF YOU STAY LESS THAN 6 MONTHS..........0

THE LIVING AND READJUSTMENT ALLOWANCES ARE SUBJECT TO INCOME TAX, SOCIAL SECURITY, AND ALLOTMENT DEDUCTIONS, IF ANY.

<u>DO I GET A CLOTHING ALLOWANCE?</u> YES, AFTER 90 DAYS OF SATISFACTORY SERVICE IN THE PROGRAM, YOU ARE ENTITLED TO A $150.00 CREDIT FOR CLOTHING. AFTER SEVEN MONTHS IN THE PROGRAM, YOU WILL ALSO BE ENTITLED TO A SUPPLEMENTAL ALLOWANCE OF $127.00 AND AFTER ONE YEAR, $103.00.

THE FOLLOWING RULES APPLY TO YOUR CLOTHING ALLOWANCE:

A. YOU MUST PURCHASE ONE ALL WEATHER COAT WITH YOUR FIRST CLOTHING ALLOWANCE.

B. MONEY NOT SPENT FOR CLOTHING WILL NOT BE GIVEN TO A STUDENT IN CASH AND A CREDIT WILL BE CARRIED OVER TO YOUR ACCOUNT.

<u>WHAT DO I DO ABOUT LOST OR STOLEN PROPERTY?</u> ALL STUDENTS ARE ENCOURAGED FIRST TO PROPERLY MARK ALL ITEMS OF ISSUED (GOVERNMENT) AND PERSONAL BELONGINGS. YOU WILL BE GIVEN INSTRUCTIONS ON HOW TO MARK CLOTHING. DO NOT MARK, CUT, TEAR, OR DEFACE GOVERNMENT ISSUED CLOTHING, AS YOU WILL HAVE TO PAY FOR IT!!!! IF CLOTHING IS TAKEN FROM YOU, CONTACT YOUR GROUP LEADER, WHO WILL FILL OUT A STOLEN PROPERTY REPORT AND WILL INVESTIGATE THE LOSS. IF IT IS CLEAR THAT YOU WERE NOT NEGLIGENT, YOUR PROPERTY WILL BE REPLACED FREE. IF NOT, YOU WILL HAVE TO PAY FOR IT.

WHERE CAN I KEEP MY EXTRA MONEY? ALL STUDENTS ARE STRONGLY ADVISED TO USE THE SERVICES OF THE STUDENT BANK OPERATED IN THE STUDENT ACTIVITIES BUILDING (CAB). ALTHOUGH NO INTEREST IS PAID YOUR MONEY IS SAFEGUARDED. DO NOT KEEP MONEY IN YOUR LOCKER! YOU CAN OPEN A SAVINGS ACCOUNT FOR AS LITTLE AS $1.00.

WHEN IS THE BANK OPEN? THE STUDENT BANK IS OPEN DURING THE EVENING HOURS MONDAY THROUGH FRIDAY.

WHY SHOULD I SAVE MONEY? YOU WILL NEED EXTRA MONEY FOR OVERNIGHT TRIPS, SPECIAL PASSES, AND WHEN YOU TAKE YOUR HOME LEAVE OR GO ON A JOB. IF IT IS IN THE BANK, YOU DON'T HAVE TO WORRY ABOUT IT.

WHO CAN I TALK TO ABOUT A PERSONAL PROBLEM? ALL THE STAFF MEMBERS AT TIMBER LAKE ARE HERE TO HELP YOU SOLVE PERSONAL PROBLEMS. LET ANY OF THEM KNOW. IN SOME CASES THEY MAY REFER YOU TO ONE OF THE STAFF COUNSELORS.

WHAT DORM WILL I BE IN? YOU WILL BE IN THE ORIENTATION DORM UPON YOUR ARRIVAL TO THIS CENTER AND AFTER A THIRTY DAY PHASE OUT SITUATION YOU WILL GO TO THE DORM OF YOUR TRADE.

WHERE CAN I SECURE VALUABLE ARTICLES? PERSONAL ITEMS SUCH AS WATCHES, CAMERAS, TAPE RECORDERS, ETC. WILL BE PLACED IN THE SECURITY SAFE. YOU WILL BE GIVEN A HAND RECEIPT AS PROOF OF OWNERSHIP. SEE YOUR DORM GROUP LEADER ON THIS MATTER.

WHERE CAN I GET A SNACK ON CENTER? AT THE STUDENT COMMISSARY LOCATED IN THE STUDENT LOUNGE. HOURS OF OPERATION VARY THROUGHOUT THE WEEK. CHECK YOUR DORM BULLETIN BOARD FOR CURRENT HOURS OF OPERATION.

HOW CAN I GET MY CLOTHES WASHED? WASHING MACHINES AND DRYERS ARE PROVIDED, IN EACH DORM, FOR YOUR CLOTHING. CHECK LAUNDRY SCHEDULES AND RULES THAT ARE POSTED IN YOUR DORM.

HOW DO I RECEIVE MAIL? YOU WILL RECEIVE YOUR LETTERS AND PACKAGES AT THE STUDENT ACTIVITIES BUILDING. FIRST YOU CHECK THE MAIN BULLETIN BOARD OR THE FRONT OFFICE WINDOW OF THE ACTIVITIES BUILDING TO SEE IF YOUR NAME IS ON THE LIST. NEXT, IF YOUR NAME IS ON THE LIST, GO TO THE SIDE WINDOW OF THE BUILDING, SHOW YOUR IDENTIFICATION CARD AND SIGN FOR YOUR MAIL MAIL CALL IS AT 4 PM WEEKDAYS AND ON SATURDAY AT 12 NOON.

CAN I EXCHANGE CLOTHING IF IT DOSN'T FIT? YES, YOU CAN EXCHANGE CLOTHING AT THE WAREHOUSE AS PER POSTED SCHEDULE. SEE YOUR DORM BULLETIN BOARD.

IS THERE A PHONE THAT I CAN USE? YES, THERE ARE PAY PHONES LOCATED IN THE DORMITORIES. SO THAT OTHER STUDENTS CAN USE THE PHONE PLEASE LIMIT YOUR CALLS TO 10 MINUTES. YOUR PHONE NUMBER HERE IS: 503-834-2291. IF YOU ARE CALLING FROM PORTLAND OR ESTACADA, OREGON, CALL 630-4291.

HOW CAN I GET A GOVERNMENT DRIVERS LICENSE? STUDENTS WITH VALID OUT OF STATE LICENSE MAY BE ISSUED A U.S. GOVERNMENT (SF-46) LICENSE PROVIDING:

(1) VOCATIONAL SUPERVISOR REQUESTS THE ACTION TO THE DRIVERS TRAINING INSTRUCTOR. ON THE BASIS THAT THE STUDENT NEEDS A LICENSE TO DRIVE AS A PART OF THE VOCATIONAL TRAINING.

(2) STUDENTS MUST HAVE A VALID STATE OF OREGON OR VALID OUT OF STATE DRIVERS LICENSE.

(3) GOVERNMENT LICENSE ARE ONLY TO BE USED TO DRIVE ON CENTER PROPER.

STUDENTS WITHOUT VALID OUT OF STATE LICENSE OR OREGON WILL BE SCHEDULED INTO DRIVER'S EDUCATION PROGRAM BY THE DRIVER TRAINING INSTRUCTOR. STUDENTS WITH THE MOST TIME IN THE PROGRAM WILL BE PICKED FIRST. STUDENTS MUST ATTEND ALL CLASSROOM AND IN CAR CLASSES.

HOLIDAYS WE OBSERVE

NEW YEAR'S DAY..............................JANUARY 1

WASHINGTON'S BIRTHDAY.........THIRD MONDAY IN FEBRUARY

MEMORIAL DAY...................... LAST MONDAY IN MAY

INDEPENDENCE DAY........................... JULY 4

LABOR DAY...................FIRST MONDAY IN SEPTEMBER

COLUMBUS DAY..................SECOND MONDAY IN OCTOBER

VETERAN'S DAY.................FOURTH MONDAY IN OCTOBER

THANKSGIVING DAY...........FOURTH THURSDAY IN NOVEMBER

CHRISTMAS DAY.............................DECEMBER 25

WEEKEND PASSES ARE A PRIVILEGE AND ONLY DESERVING STUDENTS MAY RECEIVE PASSES.

AREA CHURCHES

ESTACADA

NEW LIFE CENTER OF ESTACADA

BAPTIST

FIRST BAPTIST CHURCH

METHODIST

METHODIST CHURCH OF ESTCADA

CATHOLIC

ST. ALOYSIUS CATHOLIC CHURCH

PRESBYTERIAN

PRESBYTERIAN CHURCH OF ESTACADA

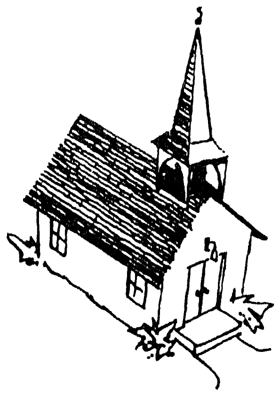
PORTLAND

BAPTIST

CATHOLIC

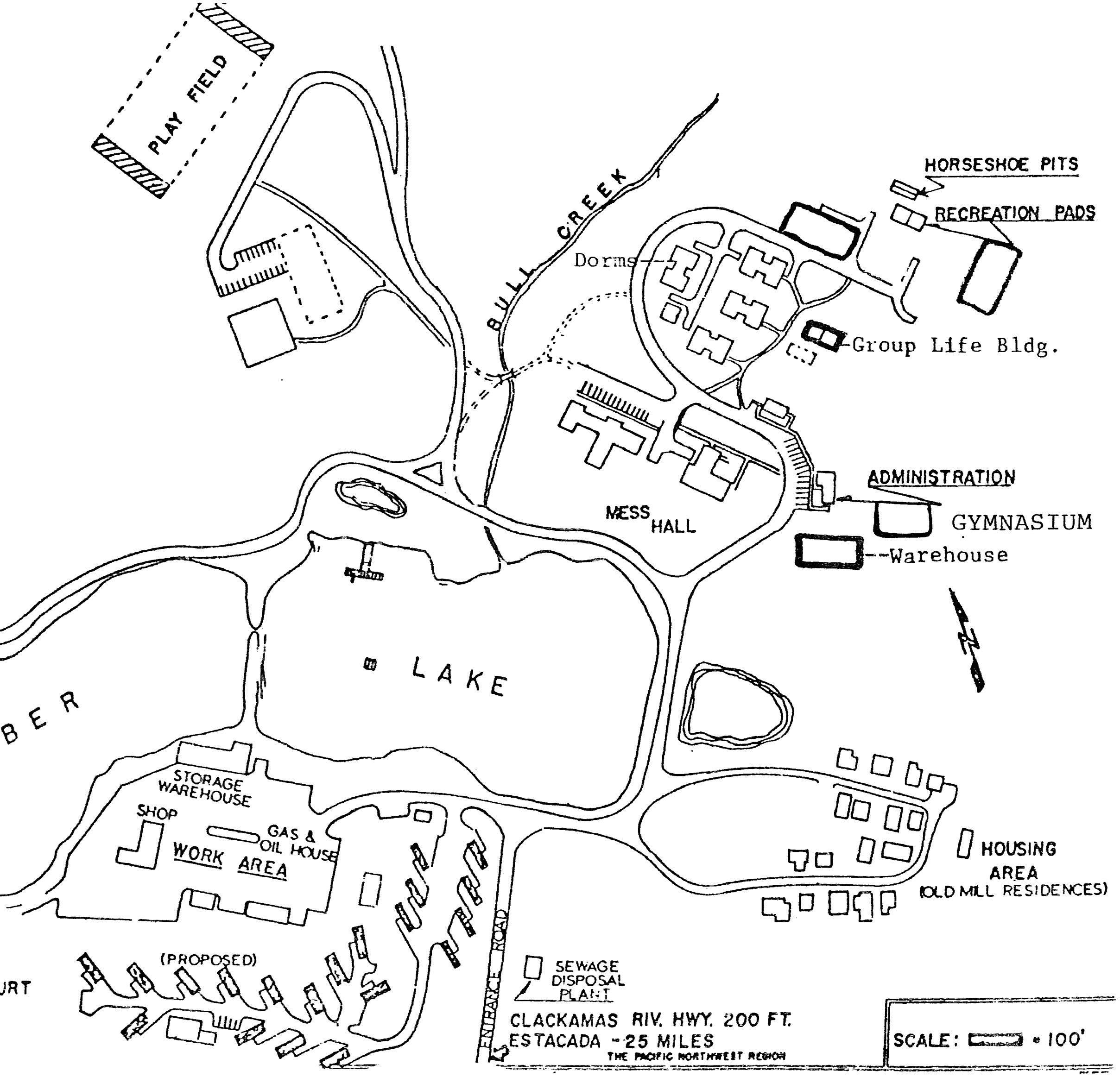
METHODIST

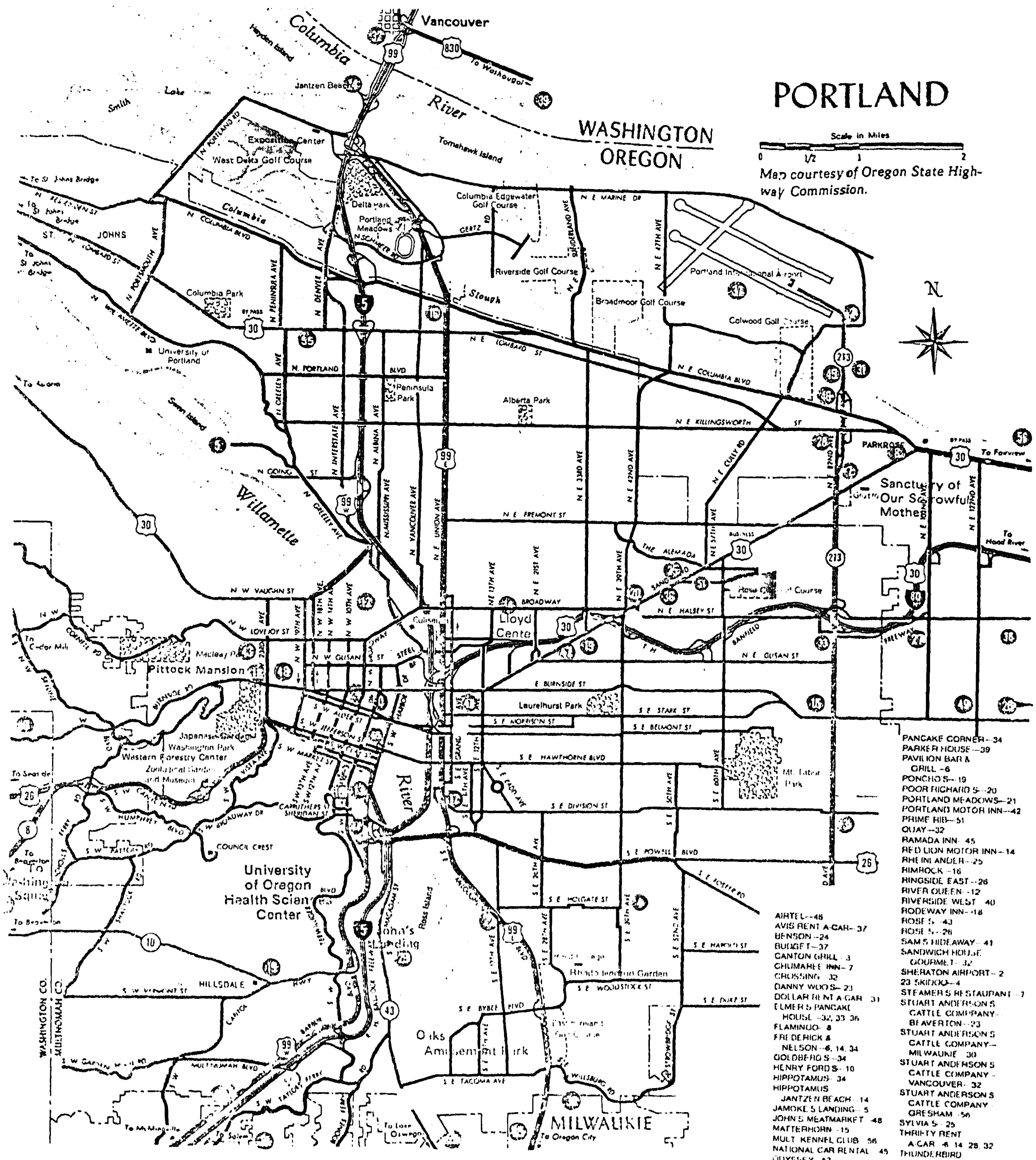
PRESBYTERIAN



TIMBER LAKE JOB CORPS
CONSERVATION CENTER

MT HOOD NATIONAL FOREST




PORTLAND
Scale in Miles
0 1/2 1 2
Map courtesy of Oregon State Highway Commission.
WASHINGTON
OREGON
Vancouver
Columbia River
Willamette River
Jantzen Beach
Exposition Center
West Delta Golf Course
Delta Park
Portland Meadows
Columbia Edgewater Golf Course
Riverside Golf Course
Broadmoor Golf Course
Colwood Golf Course
Columbia Park
University of Portland
Peninsula Park
Alberta Park
Parkrose
Sanctuary of Our Sorrowful Mother
Lloyd Center
Coliseum
Pittock Mansion
Laurelhurst Park
Japanese Garden
Washington Park
Western Forestry Center
Mt. Tabor Park
University of Oregon Health Sciences Center
Council Crest
John's Landing
Ross Island
Hillsdale
Oaks Amusement Park
MILWAUKIE
To Oregon City
Washington Co.
Multnomah Co.
PANCAKE CORNER—34
PARKER HOUSE—39
PAVILION BAR & GRILL—6
PONCHO'S—19
POOR RICHARD'S—20
PORTLAND MEADOWS—21
PORTLAND MOTOR INN—42
PRIME RIB—51
QUAY—32
RAMADA INN—45
RED LION MOTOR INN—14
RHEINLANDER—25
RIMROCK—16
RINGSIDE EAST—26
RIVER QUEEN—12
RIVERSIDE WEST—40
RODEWAY INN—18
ROSE'S—43
ROSE'S—26
SAM'S HIDEAWAY—41
SANDWICH HOUSE GOURMET—32
SHERATON AIRPORT—2
23 SKIDOO—4
STEAMER'S RESTAURANT—7
STUART ANDERSON'S CATTLE COMPANY—BEAVERTON—23
STUART ANDERSON'S CATTLE COMPANY—MILWAUKIE—30
STUART ANDERSON'S CATTLE COMPANY—VANCOUVER—32
STUART ANDERSON'S CATTLE COMPANY—GRESHAM—56
SYLVIA'S—25
THRIFTY RENT-A-CAR—6, 14, 28, 32
THUNDERBIRD JANTZEN BEACH—14
WOODEN HORSE—29
ZAPATA'S—18, 44
AIRTEL—48
AVIS RENT-A-CAR—37
BENSON—24
BUDGET—37
CANTON GRILL—3
CHUMAREE INN—7
CROSSING—32
DANNY WOO'S—23
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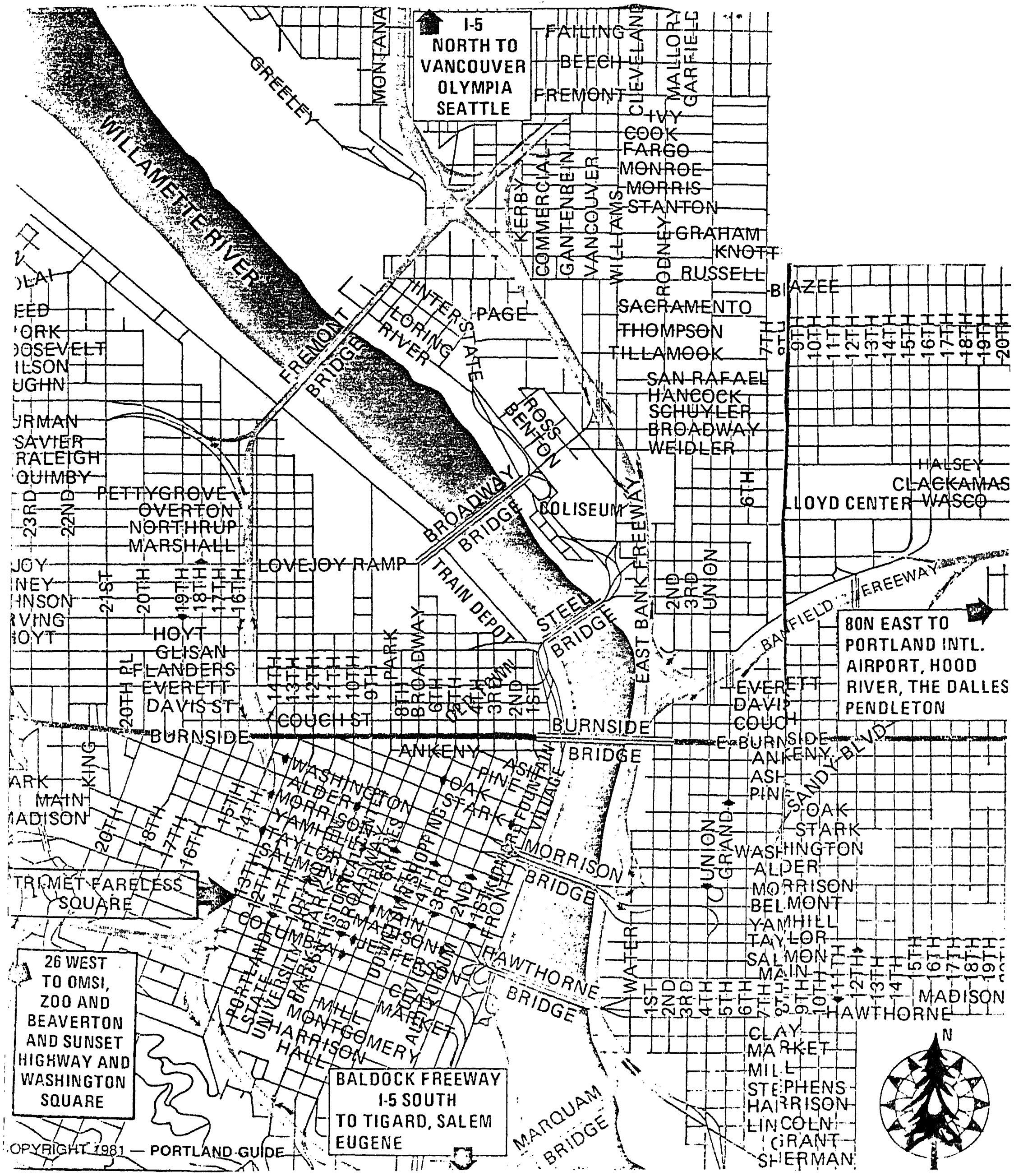

I-5 NORTH TO VANCOUVER OLYMPIA SEATTLE
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MORRISON BRIDGE
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EAST BANK FREEWAY
BANFIELD FREEWAY
SANDY BLVD.
INTERSTATE
GREELEY
MONTANA
FAILING
BEECH
FREMONT
CLEVELAND
MALLORY
GARFIELD
IVY
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MONROE
MORRIS
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TILLAMOOK
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SCHUYLER
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LORING
RIVER
ROSS
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NORTHRUP
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EVERETT
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ANKENY
ASH
PINE
OAK
STARK
WASHINGTON
ALDER
MORRISON
YAMHILL
TAYLOR
SALMON
MAIN
MADISON
JEFFERSON
COLUMBIA
CLAY
MARKET
MILL
MONTGOMERY
HARRISON
HALL
STEPHENS
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GRANT
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QUIMBY
RALEIGH
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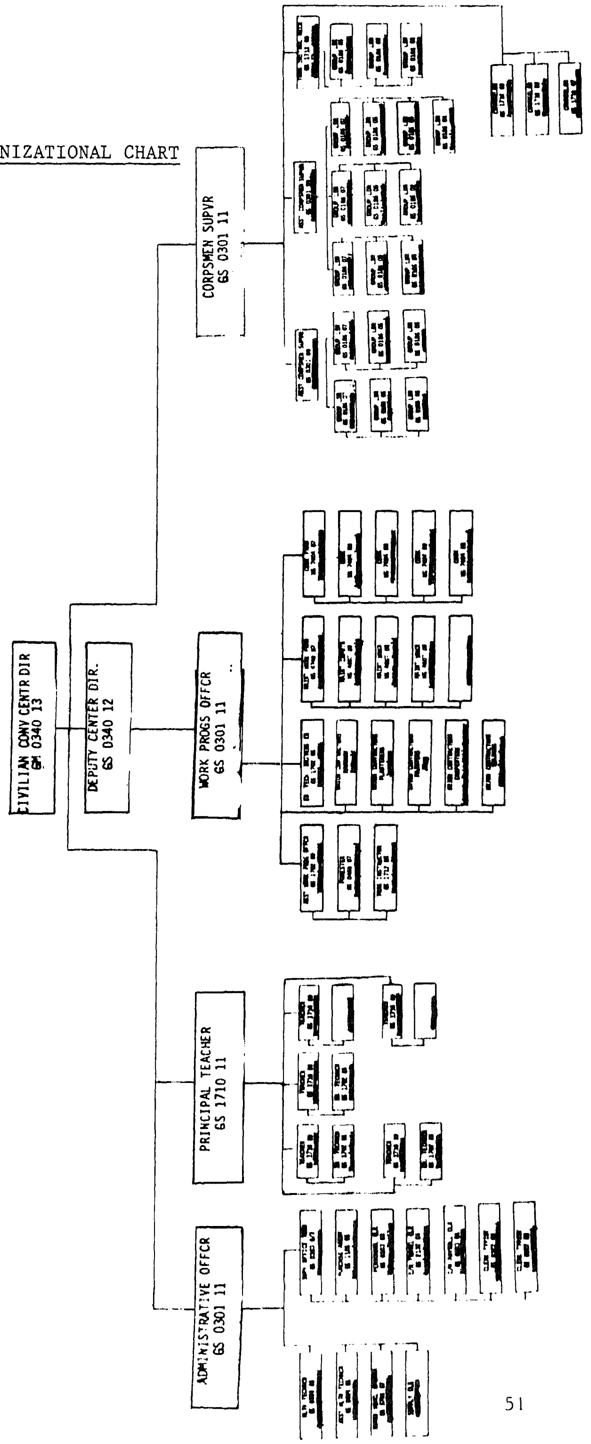
ORGANIZATIONAL CHART



TIMBER LAKE DISCIPLINE AND INCENTIVE GUIDE

DEFINITION AND APPLICATION OF DISCIPLINE

Discipline has many different meanings to many different people; to some the word implies training; to others punishment; to some it implies constructive action; and to others it implies destruction. The definition of discipline here at Timber Lake is as follows:

> Discipline is a teaching method used by the Timber Lake staff to assist students in learning to develop direction, values, self-control and responsibility in a positive and common sense manner.

THE APPLICATION OF DISCIPLINE

A. Considerations for staff:

In applying disciplinary measures to students, we need to ask ourselves exactly what we are trying to accomplish with each action. Therefore, we should consider the following:

1. Are you trying to teach the students to use self-discipline or is your action merely to satisfy your own anger or frustrations? Are you merely getting even for the trouble he/she has caused you?

2. Is your disciplinary action going to teach students to do better and apply self-discipline in his/her life?

3. Are you sure the person is guilty? Disciplining an innocent person will probably cause many additional problems and difficulties which could have been prevented. It will also cause you to lose some of your effectiveness as a staff member.

4. What is your attitude when you administer discipline? Is it calm and rational? If it is, you have taken the first step toward creating a learning situation for the students. If you are irate or irritated to the point of losing self-control, it might be better to wait until you have better control of yourself and the situation. In other words, "Don't blow your cool!" Stay in control of your behavior.

5. What is the attitude of the student at the time discipline is administered? If a student is extremely angry, belligerent or under the influence of alcohol, it would be better to merely bring the situation under control and wait until later when the incident can be discussed more intelligently. Leave the student with a time and place to meet to discuss the situation.

6. Did you discuss the regulations broken and why a particular rule is necessary? Many times when acts of misbehavior are explained to assist the student in gaining insight and understanding, he/she develops more respect for Center rules and regulations.

7. What will be your attitude toward the student after discipline has been served? Are you going to label a person after he/she commits a number of offenses? While we cannot ever completely forget the past, it is unfair to limit a person's chances for the future by waiting to pounce on him/her again. Give the student a chance. We as staff <u>should</u> be too big to hold grudges. Let a person stand or fall on their own merits. Give them a chance to correct their mistake.

8. Remember, staff must set an example for students. The students will mirror staff attitudes and behavior.

To the greatest practical extent discipline problems should be approached through informal guidance by staff members, positive incentives for good behavior and constructive criticism from peers and staff at group discussions of counseling sessions. Self-discipline is the best discipline and represents maturity; and one of the characteristics Job Crops tries to help its enrollees achieve is self-discipline.

<u>RESPONSIBILITIES FOR DISCIPLINE</u>

A. Center Standards Officer (C.S.O.)

The Corpsmember Supervisor and assistants have the responsibility as Standards Officers to keep a complete record of all disciplinary action taken against each student on Center.

The C.S.O. will monitor the behavior reports and incidents of of a serious nature indicating a disciplinary problem. The C.S.O. will review each write-up for conformity and will return any not in line with the guidelines. He will also conduct investigations to determine the facts prior to assigning penalties. The Supervisor or his assistants will determine when they should sit down with a Corpsmember to discuss his/her behavior.

B. Student Leaders

Student Leaders may make a recommendation to their supervisor for disciplinary action whenever rules or regulations have been broken. Student Leaders special behavior reports must be co-signed by staff. A write-up should be made only after a staff member has attempted to resolve the issue at hand, and has conducted an investigation to determine the facts.

C. Staff Members

All staff members have full authority and a responsibility to enforce Center rules and regulations. Staff will complete an incident report on all acts of misconduct. Each staff is to handle problems as they occur to the best of their ability and RECOMMEND action to be taken to their department heads. The section heads can approve or disapprove the recommended action.

D. Department Heads

These people will be responsible for checking out or investigating behavior reports in their own section and recommending appropriate action. Each may keep track of student's behavior in their section by weekly review of the behavior log, by keeping track of the number of incidents on a roster or whatever means they feel are best. The important thing is that developing patterns of poor behavior on the part of an individual student be recognized early and dealt with as soon as possible.

E. Center Director

The Center Director has final and full responsibility for all Center discipline. The Deputy Center Director is responsible for the day to day management and review of the overall system.

F. Performance Evaluation Panel (P/PEP)

The P/PEP will function as a counseling group for a student when the number of negative reports received indicate the student has a behavior problem that needs to be corrected. The P/PEP can initiate contracts with a student for improved behavior and it may make the recommendations on disciplinary actions when requested by C.S.O.

DISCIPLINARY PROCEDURES

A. Counseling Documentation

The first step in any disciplinary action is counseling of the student by the staff who witnessed the negative behavior. All counseling will be documented on a Behavior Report, and submitted to the CSO-C/M Supervisor via departmental heads. In the case where a negative report is written counseling will automatically be documented, a separate document is not needed.

B. Initiating and Processing Behavior Reports

Staff will use Behavior Reports to document both positive and negative behavior according to individual circumstances and disciplinary guides.

1. Four copies will be prepared. Be certain that the form is filled out properly and is signed by the person reporting it and by the student involved. It must be expained that signing the report is not an admission of guilt. If the student has not signed it or an indication of his/her refusal noted, the behavior form will be returned to the originator.

2. The student involved should be told precisely what the behavior report is for and what disciplinary action is being recommended. At this point, the offender should be counseled. Counseling should be on a one-to-one basis away from other students. The rule broken should be explained to him/her and an attempt made by the staff member to settle the matter with the student right then.

3. All behavior reports will then be submitted to the department head. He/She, in turn, will check them out, insure that they are correct and reasonable and forward them to the Standards Officer who will place them in the depository kept at the Social Living Office for proper disposition and recording. All copies should be deposited no later than 24 hours after the incident occurs.

4. The Standards Officer will record all incidents of misconduct on the file card kept for each student. He will also verify that the proper penalties for infractions are used as laid out in the guidelines later in this manual.

5. After recording in the behavior log, the behavior reports will be routed in the following manner:

   a. White copy will remain in the Social Living office to be filed in the student's folder for reference and to be used as an aid in counseling when necessary.

b. The yellow copy is sent to the Group Leader for information and counseling.

c. The pink copy will be returned to the department originating the report for information as to final disposition.

d. The blue copy will be sent to the counselor for information.

APPEAL ACTIONS

The right to question or disagree with specific disciplinary actions is part of the total program. Listening and hearing the other side of the issue is vital. Applying disciplinary action arbitrarily or unfairly can make the entire program ineffective. Therefore, we must provide and use an appeal system.

A. Basically, no disciplinary action should go into effect until an appeal is resolved. Unusual or individual circumstances may require immediate implementation of an action despite an appeal. However, these cases should be minimal in number.

B. The Behavior Report (MHTL 6170-13) has an appeal section. Individuals must be informed of their right to appeal before they sign the report. Their failure or refusal to sign does not give them an "automatic" appeal. Staff should briefly note why the report is not signed.

C. The first level of appeal is to the staff's supervisor or department head. The second level of appeal is to the C.S.O.. The final level would be the Center Director.

D. Once an appeal goes beyond the Center Standards Officer, documentation should be written. If a student is unable to prepare a written statement the C.S.O. will appoint a staff member to assist. The written appeal should contain enough information including supporting data to allow for a decision.

E. Appeal process is limited to 14 days from the date the appeal is initiated.

REVIEW BOARD

The Center Review Board (C.R.B.) is the last step in the Job Corps disciplinary system.

The C.R.B. is the only approved procedure for recommending a disciplinary discharge for a student except in the following instances:

1. Conviction of a felony
2. Confinement more than 60 consecutive days

The Center Director has the ultimate responsibility and authority for approving a disciplinary discharge.

All staff have the responsibility to follow the disciplinary system outlined in the Job Corps Residential Living Manual, Section VIII.

The C.S.O. has the responsibility to insure that all possible means to change a student's behavior, in accordance with the disciplinary system, have been met before recommending a C.R.B. be called.

When the C.S.O. recommends that student goes to the C.R.B. the following steps must be followed:

1. Conduct a thorough investigation of the incident.
2. Prepare a written C.S.O. report giving the facts, charges, statements and recommendations.
3. Prepare a C.R.B. packet consisting of:
   a. ET 6-131 Packet Information for Disciplinary Discharge Cases
   b. MA 6-131A Notice of Hearing and Appraisal of Rights
   c. MA 6-131B Summary of Review Board
   d. ET 6-131C Corpsmember Right to Make Statement
   e. ET 6-131D Corpsmember Right to Appeal to Regional Office
4. Present all above material and entire discipliarny record to Center Director for review and approval.
5. If the Center Director approves the C.R.B. the following step must be followed:

   Center Director informs C.R.B. Chairperson that packet is approved and C.R.B. needs to be scheduled.
6. C.R.B. Chairperson notifies student at least 24 hours in advance of C.R.B. advises student of his/her rights, has student sign MA 6-131, and advises studen of appeal rights.

As a student representative you have the following obligations:

1. Review and understand the charges, recommendations and record of the case and the student you are representing.
2. Review the charges and the student's statement in answer to these charges with the student to insure full understanding.
3. Prepare or make a statement on the behalf of the student and in mitigation of possible punishment.
4. Assist the accused student to the very best of your ability during the hearing regardless of personal feelings about the case.
5. Assist the student in preparing an appeal statement if necessary.

GOVERNMENT PROPERTY LOST OR DESTROYED

A. Payment of costs or for damages in excess of \$5.00 (not to exceed (\$300.00).

   1. Behavior Reports MHTL 6170-13, along with a completed Job Corps Living Allowance and Allotment Change Notice, JC-12, will be initiated and forwarded through department heads to Corpsmember Records Clerk.
   2. Partial collections will be made in payline using Bill for Collection, FS 6500-89.
   3. Amounts collected will be accumulated by the Corpsmember Records Clerk and deposited to appropriate Center accounts through Bill for Collection procedures.

B. Controls and Exceptions

   1. No collections will be made which will reduce an individual's pay to less than \$ 7.00.
   2. No more that \$5.00 will be collected from any individual each pay day for a fine.
   3. Students who terminate prior to completion of payment obligations will:
      a. Have balance deducted from cash payment of readjustment allowance prior to leaving Center.
      b. Have a JC-12 processed to provide for collection by Finance Center.
   4. All fines will be deposited in Student Council account.

Offenses for which a disciplinary discharge may be recommended by the C.S.O. are as follows:

1. Physical assault with clear intent to inflict severe bodily harm, especially if a weapon is used.
2. Possession of a dangerous weapon.
3. Participation in coercive or disruptive sexual activity.
4. Making drugs available on a Job Corps Center and/or on Federal property
5. Engaging in lending money at interest, or extortion (including protection rackets and related conduct.)
6. Persistent failure to observe Center regulations.
7. Disruptive behavior which seriously interferes with the interests of other students or staff.
8. Repeated or prolonged absenses from duty without permission.

The C.R.B. must consist of an odd number of members. Decisions shall be made by vote of a simple majority. The Chairperson should vote only to break tie votes. (More than one student can be used.)

Chairperson - Only Key Staff or GS-9 Supervisors will be eligible. Must have previous experience on board. Selections will be made by Director or Deputy. Chairpersons will serve one year term.

Board Members - Members will serve one year terms. Vocation, Administration, and Education will select a member and an alternate. The alternate will replace the member on the board when the member's term expires. Any one of the three officers of the Corpsmember Council will serve as student representative on the board.

C.S.O. and Counseling will not have representatives on the board.

The C.R.B. has certain basic responsibilities which are to be followed:

1. Help student in any way possible.
2. Assure that the students personal rights are fully protected.
3. Evaluate all Center actions and procedures which may have been either positive or negative influences.
4. Recommend any action which may be necessary to protect the Center or individuals or bring about a positive change in the student.
5. Avoid any action or procedure that could be considered a means to "railroad" a student out of the program.
6. Advise and make sure the student understands all appeal rights available to them.

The student appearing before the C.R.B. has the right to proper representation of his/her choice. If the staff requested by the student is not available, the Chairperson should appoint a staff member as a representative that is acceptable to the student. If the student chooses not to have a representative then he/she must so indicate by signature on the MA 6-131A, Notice of Hearing and Appraisal of Rights.

GENERAL RULES FOR STUDENTS

A. The sale, possession or consumption of alcoholic beverages is prohibited.

B. Students shall meet work, instructional, medical and counseling appointments promptly and comply with proper instructions.

C. Respect shall be demonstrated for the rights, privileges and needs of others.

D. Reasonable care shall be exercised in the use of Center facilities and equipment. Regulations relating to safety in the use of equipment will be complied with.

E. Possession of a personal weapon such as a firearm, a switch-blade, straight razor or blackjack is prohibited.

F. Gambling on Center is prohibited.

G. Hazing in any form is not permitted.

H. Physical aggression as a means of settling differences will not be tolerated.

I. Maintaining or operating private vehicles on the Center premises is prohibited.

J. Permission is required to leave the Center during off-duty hours. A sign-in/out register is used to aid student accountability. It is the student's responsibility to stay away from off-limit areas.

K. Reasonable standards of personal appearance and cleanliness will be established by the Center Director, who will consider recommendations of the Student Government in establishing such standards.

L. All sexual activities are prohibited on Center

M. Hitchhiking by students is against the Center rules.

N. The sale, possession and trafficing of drugs or controlled substances is prohibited.

O. Tattooing is prohibited.

P. Inappropriate use of fire safety equipment is prohibited.

Q. Wasting food and removing food or dishes from mess hall is prohibited.

R. Theft or possession or selling of stolen goods is prohibited.

S. Being in the following off-limit areas is prohibited

1. Downriver from the Center
2. Three Lynx
3. Ripplebrook
4. Frog Lake
5. Pipeline
6. Center staff housing areas
7. Oakgrove
8. Silvertip

DISCIPLINE GUIDELINES

The following discipline guidelines were established by representatives of Vocation, Counseling, Group Life, Education and the Student Council. The guidelines are based on classes from I to VIII with I being the least serious and VIII the most serious. The discipline is very specific to insure equal treatment of all students.

Please note that for classes I and II writing a negative report is up to the staff. Staff will document counseling and if the C.S.O. observes that a student has been counseled by different staff for the same problem on different occasions (i.e. a negative behavior trend is established) he will consult all staff involved and determine if a negative report and discipline is appropriate.

There will be a limitation on how long negative reports will be counted against a student when determining the level of

discipline. The limitations will be 30 days for Classes I and II, and 90 days for Classes III and above.

A $5.00 fine will automatically be levied for any missed medical or dental appointments, on or off Center.

Failure to work extra duty in alloted time will result in restriction (not to exceed 30 days.).

A. Class I - Non-Performance

Includes:
a. Failure to perform assigned duties. (All areas)
b. Late sleeping
c. Improper dress, appearance or personal hygiene. Any other incidents which would fall into category of non-performance.

Discipline: Minimum - Counseling, no negative report
1 - 2 reports - Counseling, $1.00 fine, 4 hours extra duty
3 reports - Counseling, $2.00 fine, 4 hours extra duty
4 reports - Counseling, $4.00 fine, 6 hours extra duty
1 week restriction
Maximum C.R.B. - 5 reports within 30 days.

B. Class II - Failure to observe Center rules and regulations

Includes:
a. Cutting in Line (pay, Dining Hall, PX, etc.)
b. Horseplay
c. In unauthorized area.
d. Loud music, loud talking, before lights out.
e. Posted rules (Gym, Education, Dining Hall, etc.)
f. Failure to comply with safety regulations
g. Wasting food
h. Feeding ducks and /or geese around Dining Hall
i. Littering
j. Insubordination

Discipline: Minimum - Counseling, no negative report
1 - 2 reports - Counseling, $2.00 fine, 4 hours extra duty
3 - 4 reports - Counseling, $5.00 fine, 8 hours extra duty
2 weeks restriction
Maximum C.R.B. - 5 reports within 30 days

C. Class III - Absent from assigned areas

Includes:
a. Absent from assigned area
b. Out of dorm after lights out
c. In dorm without a pass

Discipline: 1 report - Counseling, $2.00 fine, 4 hours extra duty,
1 week restriction

2 reports - Counseling $3.00 fine, 8 hours extra duty
2 weeks restriction
3 reports - Counseling, $5.00 fine, 16 hours extra duty
30 days restriction
Maximum C.R.B. - 4 reports within 30 days

D. Class IV - AWOL

Includes:
a. Anywhere down river or Estacada
b. Extended AWOL from Center
c. Violation of Hiking Policy
d. Hitchhiking or in unauthorized vehicle
e. Violation of Pass Policy. Unless violation requires special transportation. See Restitution.

Discipline:
1 report - Counseling, $5.00 fine, 8 hours extra duty, 2 weeks restriction
2 reports - Counseling, $5.00 fine, 16 hours extra duty, 30 days restriction
3 reports - C.R.B.

There will be a loss of pay and allowances for AWOL after first day. Restitution of cost for C/M to be picked up when a special trip or arrangement has to be made.

AWOL will be: Between Center And Estacada $10.00
Beyond Estacada $20.00

E. Class V - Use or Possession of small quantities of drugs or alcohol.

Discipline:
1 report - Counseling, $3.00 fine, 8 hours extra duty, 1 week restriction
2 reports - Counseling, $5.00 fine, 16 hours extra duty, 2 weeks restriction
3 reports - C.R.B.

Furnishing, sale, or possession of large quantities of alcohol or drugs.

Discipline:
1 report - Counseling, $5.00 fine, 32 hours extra duty, 30 days restriction
2 reports - C.R.B.

F. Class VI - Interferance with Rights of Others (minor)

Includes:
a. Insubordination (verbal Abuse)
b. Fighting
c. Verbal harassment (profanity, sexual harassment)
d. Disrupting; class, vocational crew, dorm.
e. Misuse, damage or destruction of property
* f. Out of bed, music, talking after lights out.
g. Safety violation which causes physical endangerment
h. Any other activity which interferes with rights of others
i. Misuse of Pride Card, Leadership Card, C/M Government Card, or false use of I.D.

* Staff will confiscate music equipment to be stored in warehouse after first offense.

Discipline: 1 report - Counseling, $5.00 fine, 8 hours extra duty, 1 week restriction.

2 reports - Counseling, $5.00 fine, 12 hours extra duty, 2 weeks restriction.

3 reports - Counseling, $5.00 fine, 12 hours extra duty, 30 days restriction.

Maximum - Center Review Board.

G. Class VII - Disruptive behavior which seriously interferes with the Rights of Others

A. a. Extortion

b. Loansharking

c. Threats or pressuring (hazing)

d. Theft or breaking and entering, and possession of stolen goods.

e. Misconduct off Center.

f. Forceful or aggressive sexual or homosexual activities.

g. Assault

h. Encouraging or inciting others to perform disruptive acts.

i. Possession of weapons.

* j. Minor court charges (infractions/citations).

k. Gambling

Discipline 1 report - Counseling, $5.00 fine, 24 hours extra duty, 30 days restriction.

C.R.B.

* In cases where special trips have to be made a $20.00 restitution fee will be required.

B. Specific rules regarding conduct of Corpsmembers using public tranportation.

a. Using loudand abusive language.

b. Possessing or consuming alcoholic beverages.

c. Possessing or using drugs.

d. Taking property belonging to others.

e. Playing radios loudly.

f. Engaging in fighting.

g. Interfering, in any way, with the driver of a bus in carrying out their responsibility.

h. Vandalism of buses, depots or other property.

Discipline: 1 report - Counseling, $5.00 fine, 24 hours extra duty, 30 days restriction.

C.R.B.

* In cases where special trips have to be made a $20.00 restitution fee will be required.

* It is noted that any corpsmember who engage in such behavior while using public transportation may be subject to criminal prosecution by the carrier and/or passengers involved.

H. <u>Class VIII</u>

Includes: Conviction of criminal or felony charges;
Confinement under sentence for more than 60 consecutive days
Absent from duty without permission for 15 consecutive days

Discipline: Disciplinary Discharge
AWOL Discharge

Any corpsmember receiving a computation of seven negative write-ups in 90 days will go to a Center Review Board.

Any Pride Card holder will lose his privileges for 30 days for receiving a Class I or Class II behavior report. Privileges will be lost for 30 days for receiving a Class III or higher behavior report. The card will be lost for 6 months if 2 behavior reports are received within 60 days of each other.

A leader will lose the privilege card in accordance with the provisions of the leaderahip program.

A Corpsmember Council electee will lose the privilege card subject to the regulations set forth in the Corpsmember Council by-laws.

This program is designed to provide opportunities for students to earn rewards and recognition for performing useful work of a positive and beneficial nature to our Center. The Timber Lake "Positive Person."

The work done must be verified by a Center staff member and significant in time and effort to be rewarded with a positive behavior report of recognition. This work should be work accomplished outside the normal requirements of Education, Vocation or Group Life Departments, but allowing for the need to respond to a special situation on a limited basis in your normal Education, Vocation or Group Life areas, etc.

There are to be no limits as to the number of positive write-ups that can be earned within a given time period. Duration of work for a positive report should be at least ½ hour. The individual staff member will use his or her judgement in determining the accomplishment of the positive behavior report.

The Center Standard's Officer will be the person in charge of, and responsible for the Timber Lake Positive Incentive Program, documentation, monitoring and rewarding the students for positive performance.

Rewards will be as follows for total hours of positive behavior reports:

10 Positive Hours- Supervised Trip
25 Positive Hours - Trophy
50 Positive Hours - Plaque
75 Positive Hours - Job Corps Pin
100 Positive Hours - Beltbuckle (Job Corps)
150 Positive Hours - Large Job Corps Plaque
200 Positive Hours - Dinner & Movie
500 Positive Hours - 24 hour pass $ 20.00 maximum
1000 Positive Hours - 48 Hour pass $30.00 maximum

DRESS CODE AND GROOMING STANDARDS

While at Timber Lake, you will be required to meet certain standards of dress and grooming. These standards are established to protect your health and safety, as well as to reflect the changing trend in socially acceptable appearance.

A. Hair length will be determined by the Vocational Instructor in each trade, on the basis of safety and with regard to standards necessary for employment in the trade. The general rule is that hair should not be so long as to prevent the wearing of a properly fitted hard hat nor be hanging in the way of your work.

B. On Center Leisure Code.
   1. On your free time in the dorm area you may dress casually, Shirts must be worn in all buildings except the gym and the dormitories.
   2. Shoes, sandals, and canvas shoes of any type are acceptable in the group living area.
   3. Tank top shirts, sleeveless shirts and T-shirts are acceptable on Center at any time they do not conflict with safety dress standards.

C. Education Dress Code
   1. Students must be fully attired (shoes or sandals, shirt, pants). No short pants or tank tops.
   2. Clothes will be clean & neat.

D. Dress Code For Work
   1. Standard issue work clothes for each trade will be established by the specific trade requirements, such as carpentry, plastering, cooking, welding, etc. Required items are boots, safety glasses and hard hats.

E. Dining Hall Dress Code
   1. Excessively dirty clothing will not be permitted in the dining hall at any time.
   2. Shoes of any type are acceptable, but socks are required with all.
   3. Hair is to be combed.
   4. Tank shirts are not permitted. Underwear sticking out of shorts is not permitted.
   5. NO hats.

F. Off Center Dress Code

1. No issue greens may be worn off the Center unless working off Center. They are for work and school only. Normal street clothes, such as wash and wear attire, jeans and dress slacks are permissible for off Center activities, but not sweat shirts or T-shirts.

2. All clothing worn off Center is to be clean and neatly pressed.

3. Tennis shoes, deck shoes, sandals and dress slippers are acceptable but require socks.

STUDENT WEEKEND PASS AND LIBERTY INFORMATION

	LIBERTY	24-HOUR PASS	48-HOUR PASS	72-HOUR PASS
DEPARTURE TIME	1030 HOURS SATURDAY	1030 HOURS SATURDAY	1800 HOURS FRIDAY	1800 HOURS FRIDAY
RETURN	2300 HOURS SATURDAY 3rd & Oak, Portland	1800 HOURS SUNDAY 3rd & Oak, Portland	1800 HOURS SUNDAY 3rd & Oak, Portland	1800 HOURS, MONDAY ESTACADA, CALL 630-4291 FOR TRANSPORTATION
GOOD BEHAVIOR PERIOD	60 DAYS, EXCEPT FOR FIRST OFFENSE IN CATEGORY I & II	30 DAYS, EXCEPT FOR FIRST OFFENSE IN CATEGORY I & II	30 DAYS, EXCEPT FOR FIRST OFFENSE IN CATEGORY I & II	30DAYS, EXCEPT FOR FIRST OFFENSE IN CATEGORY I & II
APPROVALS NEEDED	GROUP LEADER	GROUP LEADER	GROUP LEADER	GROUP LEADER AND INSTRUCTOR OF CLASS THAT WILL BE MISSED
MONEY NEEDED	$10.00	$15.00	$20.00	$30.00

PASS AND LIBERTY RULES:

1. LIBERTY IS A REWARD FOR EXCEPTIONAL BEHAVIOR OVER A PERIOD OF 60 DAYS. A CORPSMAN CAN HAVE NO NEGATIVE WRITE-UPS EXCEPT FOR THE FIRST OFFENSE IN CATEGORY I AND II.

2. TRAVEL TO AND FROM THE CENTER WILL BE BY GOVERNMENT TRANSPORTATION ONLY, EXCEPT BY PRIOR APPROVAL. THE MONEY NEEDED CAN BE WAIVED WHEN STAYING IN A CONFIRMED AND APPROVED FAMILY RESIDENCE.

3. VIOLATION OF THE PASS AGREEMENT AS TO DESTINATION, RETURN TIME, MEANS OF TRANSPORTATION, OR BY WAY OF IMPROPER CONDUCT WHILE ON PASS WILL RESULT IN 30 DAYS OF RESTRICTION AND WHATEVER OTHER DISCIPLINE IS CONSIDERED APPROPRIATE BY THE CENTER STANDARDS OFFICER (CSO).

4. PASS APPLICATIONS MUST INCLUDE THE CORPSMAN'S NAME AND COMPLETE ADDRESS AND TELEPHONE NUMBER WHERE HE WILL BE STAYING. THE APPLICATION MUST BE SUBMITTED BY WEDNESDAY EVENING.

5. NO PASS CAN BE AUTHORIZED WHICH ALLOWS THE STUDENT TO MISS TWO OR MORE DAYS OF CLASS TIME. LEAVE MUST BE TAKEN UNDER THESE SITUATIONS.

6. WHEN A HOLIDAY FALLS ON A MONDAY OR FRIDAY, THAT DAY MAY BE TAKEN IN ADDITION TO THE STATED PASS RESTRICTIONS.

INFORMATION REFERENCE: Center Policy #13 01/01/82

STUDENT TRIP INFORMATION

	CHURCH	SKATING	TONGUE POINT	BOWLING
DEPARTURE TIME	0915 HOURS, SUNDAY	1930 HOURS SATURDAY	PER RECREATION SCHEDULE	0930 HOURS SUNDAY
RETURN	AT THE END OF THE CHURCH SERVICE	2330 HOURS, FRIDAY FROM THE RINK	PER RECREATION SCHEDULE	1330 HOURS, FROM THE ALLEY
GOOD BEHAVIOR PERIOD	NO PREVIOUS PROBLEMS ON THE CHURCH TRIP	SEE #3 BELOW	SEE #3 BELOW AND THE BEST BEHAVIOR RECORD	SEE #3 BELOW
APPROVAL NEEDED	GROUP LEADER	GROUP LEADER	GROUP LEADER	GROUP LEADER
MONEY NEEDED	NONE	COST OF SKATING OR FREE PASS	NONE	COST OF THE EVENT OR FREE PASS

TRIP RULES:

1. OTHER TRIPS MAY BE SCHEDULED ON THE RECREATION SCHEDULE WHICH WILL GIVE THE DEPARTING AND RETURNING TIMES AND THE MONEY NEEDED FOR THE EVENT. GROUP LEADER APPROVAL IS NEEDED.

2. TRIPS TO CONCERTS HAVE A REQUIREMENT OF THE MOST RECENT THIRTY DAYS WITHOUT A NEGATIVE WRITE-UP AS ESTABLISHED BY THE CORPSMAN COUNCIL.

3. ALL TRIPS HAVE THE REQUIREMENT THAT THE CORPSMAN IS NOT ON RESTRICTION AND THAT HE DOES NOT HAVE EXTRA DUTY PENDING.

4. WHEN THERE ARE MORE CORPSMAN SIGNED UP FOR A TRIP THAN CAN BE ACCOMODATED, THE CORPSMAN WITH THE MOST RECENT NEGATIVE WRITE-UP WILL BE DROPPED FROM THE TRIP FIRST.

United States Department Agriculture | Forest Service | TIMBER LAKE CIVILIAN CONSERVATION CENTER
59868 E. Hwy 224, Estacada OR 97023

Reply To: 1850 Job Corps

June 11, 1984

Subject: Clothing Allowance Policy #18 - Revision

To: All Staff

PURPOSE: To revise the Center Policy #18 to assure consistent and uniform compliance with JC Bulletin #84-24.

JC Bulletin #84-24 changes the procedures for cash clothing allowances effective June 1, 1984. All Corpsmembers arriving on Center will be issued clothing and sundries necessary for participation in vocational training. Issued clothing shall remain the property of the government except for expendable or wornout items and special/emergency situations. Corpsmembers will be billed for any items not returned to the warehouse upon terminations. Corpsmembers are encouraged to return items that they no longer need.

The following increments will be considered in arriving at the first year's total of $317.00:

3 months - 90 day completion	$125.00
8 months - 240 day completion	$ 96.00
12 months - 360 day completion	$ 96.00

A supplemental clothing allowance of $103.00 may be authorized upon satisfactory completion of one year's service. The allowance will be used only to purchase additional or replace civilian clothing. Supplemental allowance may be given in increments of $25.74 for each three (3) month period over one year's completion. This can be accumulated to six (6) months which will give the Corpsmember a clothing run of $51.48. The last six (6) months accumulation will be $51.52, giving the Corpsmember the total of $103.00 supplemental allowance.

INITIAL CLOTHING ISSUE

The initial clothing issue upon arrival shall consist of the following:

1 pair of work boots (hard toe)
1 work jacket
2 work shirts, long sleeve
2 pair of work trousers
3 sets of underwear (shorts and T-shirts)
5 pair of socks
1 pair of tennis shoes
1 toilet kit

Issue clothing shall remain the property of the government and, except for expendable or wornout items and in special/emergency situations, shall be returned to the Center by the Corpsmember either upon termination or when no longer needed so that it may be sanitized and reissued. Additional work clothing will be issued by each trade and remain the property of the government. The recreation department issues items of clothing and protective items for participants in sporting activities which remains the property of the government with provisions given to hygiene conditions. The warehouse personnel shall give reasonable weight to the needs of the Corpsmembers when making a determination with regards to the need to return worn/used items. Clothing items which may not be suitable for re-use because of hygienic reasons should be retained by the Corpsmember, e.g. swim suit, including sneakers and hard toe shoes.

CASH CLOTHING ALLOWANCE

The cash clothing allowance will be used by Corpmembers to purchase clothing items and some accessories to supplement that initially brought with him. Such clothing will be suitable for on-Center and off-Center training and recreational purposes. Some clothing will be suitable for job interviews. Guidance will be given to each clothing run group prior to leaving the Center on purchasing trips by the day accountability person.

A suggested list of items to be purchased from cash clothing allowance is shown below. This list is provided for guidance and may be augmented by items which Centers determine to be appropriate.

Belts	Blazers	Coats
Gloves	Hats/Caps	Jackets
Pants	Scarves	Shirts
Shoes	Shorts	Slacks
Socks	Suits	Sweaters
Ties	Underwear	

SPECIAL CLOTHING ISSUE

Special clothing will continue to be issued by the area having recreation, vocation, and special clothing budgets. Please refer to JC Bulletin #84-24 for suggested clothing issues.

CLOTHING RUN PROCEDURES

The assigned staff will schedule students based on their amounts of time on Center. This list will be routed to the counseling staff prior to PEP Panels. the Pep Panel will insure that all students on the list meet a minimum of two weeks good behavior (no write-ups) prior to the clothing run. This list will be put in the P.O.D. and posted in each dorm. The clothing run will be limited to 20 students maximum. If a need arised to send more than 20 students, a second staff member will be assigned to the clothing run.

The purpose of the clothing allowance is to purchase clothing. The group leaders will advise students that they are to purchase only clothing with their allowance. Items such as hat bands, wallets, jewelry, gifts, etc. are ·t authorized.

This policy is established to recognize the student's needs and to act as an incentive for program completion. Although it is based on successfull participation and progress, it is not to replace the guidelines established for discipline.

Mack

MACK FERRICK
Center Director

FREQUENCY METERS

Frequency meters (figure 3-23) measure the cycles per second rate of alternating current. The range of frequency meters found on gas turbine ships is between 55 Hz to 65 Hz. Frequency of the a.c. used on ships rarely varies below 57 Hz and seldom exceeds 62 Hz. A frequency meter may have a transducer that converts the input frequency to an equivalent d.c. output. The transducer is a static device employing two separately tuned series resonant circuits which feed a full wave bridge rectifier. A change in frequency causes a change in the balance of the bridge. This causes a change in the d.c. output voltage.

KILOWATT METERS

Wattage is measured by computing values of current, voltage, and power factor. The kilowatt meters used on ships automatically take these values into account when measuring kilowatt (kW) produced by a generator. Kilowatt meters are connected to both current and potential transformers to allow them to measure line current and voltage. The kW meter shown in figure 3-24 is similar to the ones used on gas turbine ships. Since each type of generator on gas turbine ships is rated differently, the scale will be different on each class ship.

The amount of power produced by a generator is measured in kilowatts. Therefore, it is important when balancing the electrical load on two or more generators to ensure kW is matched. Loss of kW load is the first indication of a failing generator. For example, two generators are in parallel and one of the two units experiences a failure. To determine which of the two units is failing, you compare the kW reading. Normally, the generator with the lowest kW would be the failing unit. However, you should know that there is one case where this is not true. During an overspeed condition, both units will increase in frequency. But the failing unit will be the one with the higher kW load.

SYNCHROSCOPES

Before connecting a three-phase generator to bus bars already connected to one or more other generators, certain conditions must prevail. A synchroscope is the device you will use to find out if the following conditions have been met.

1. Phase sequence must be the same for generator and bus bars.
2. Generator and bus-bar voltage must be the same.
3. Generator and bus-bar frequency must be the same.

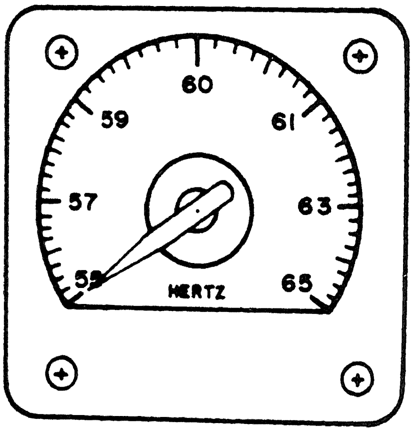


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Figure 3-23.—Frequency meter.

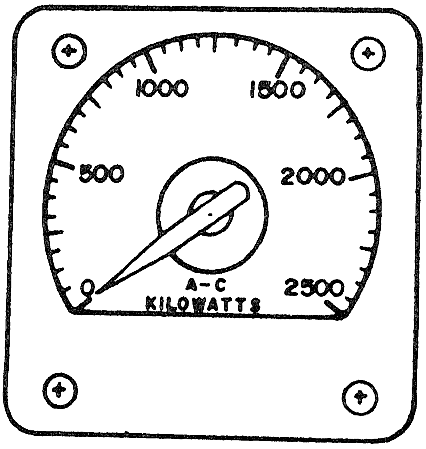

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Figure 3-24.—Kilowatt meter.

4. Generator frequency must be practically constant for an appreciable period of time.

5. The generator and bus-bar voltage must be in phase. They must reach their maximum voltages at the same time. This is so that when connected, they will oppose excessive circulation of current between the two machines.

A synchroscope is shown in figure 3-25. It is basically a power factor meter connected to measure the phase relation between the generator and bus-bar voltages. The moving element is free to rotate continuously. When the two frequencies are exactly the same, the moving element holds a fixed position. This shows the constant phase relation between the generator and bus-bar voltage. When the frequency is slightly different, the phase relation is always changing. In this case, the moving element of the synchroscope rotates constantly. The speed of rotation is equal to the difference in frequency; the direction shows whether the generator is fast or slow. The generator is placed on line when the pointer slowly approaches a mark. This mark shows that the generator and bus-bar voltages are in phase.

PHASE-SEQUENCE INDICATORS

The sequence in which the currents of a three-phase system reach their maximum values is determined by phase-sequence indicators. An example of this type of indicator is shown in figure 3-26.

Gas turbine ships have phase-sequence indicators installed in switchboards which may be connected to shore power. These instruments indicate whether shore power is of correct or incorrect phase sequence, prior to connecting shipboard equipment to shore power. Three-phase motors, when connected to incorrect phase-sequence power, rotate in the opposite direction.

The phase-sequence indicator has three neon lamps that light when all three phases are energized. A meter connected to a network of resistors and condensers shows correct or incorrect sequence on a marked scale.

SUMMARY

This chapter introduced you to many of the sensing and indicating devices found on gas turbine ships. Only the most common and frequently used devices were covered. You may come across other types of specialized sensors or indicating instruments not covered here. In this case, refer to the manufacturers' technical manuals. You have been referred to other sources of information to help you better understand the certain operational principles that were discussed in this chapter.

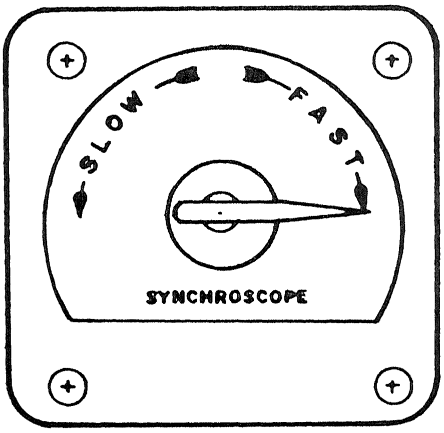

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Figure 3-25.—Synchroscope.

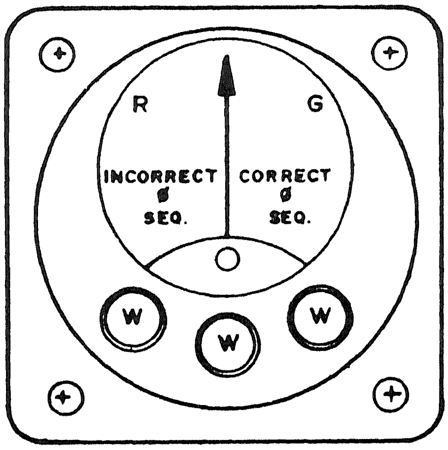

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Figure 3-26.—Phase sequence indicator.

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CHAPTER 4

FUNDAMENTALS OF GAS TURBINE ENGINES

This chapter will help you understand the history and development of gas turbines. You will become familiar with the basic concepts used by gas turbine designers. You will follow discussions of how the Brayton cycle describes the thermodynamic processes in a gas turbine. Also you will learn how various conditions and design limitations affect gas turbine performance. This information will include how the gas turbine develops and uses hot gases under pressure. You will also learn the nomenclature related to gas turbines and gas turbine technology. After reading this chapter, you will be able to describe the principal components of gas turbines and their construction.

HISTORY AND BACKGROUND

Until recent years it has not been possible to separate gas turbine technology and jet engine technology. The same people have worked in both fields, and the same sciences have been applied to both types of engines. Recently, the jet engine has been used more as a part of aviation. The gas turbine has been used for electric generation, ship propulsion, and even experimental automobile propulsion. Even now, many operational turbine power plants use an aircraft jet engine as a GG. A PT and transmission are added to complete the plant.

In nature, the squid was using jet propulsion long before our science thought of it. There were examples of the reaction principle in early history; however, practical application of the reaction principle has occurred only recently. This delay is due to slow progress of technical achievement in engineering, fuels, and metallurgy (the science of metals).

Between the first and third centuries A.D., lived Hero, a scientist in Alexandria, Egypt. He described what is considered to be the first jet engine. Many sources credit him as the inventor. True or not, a device, the aeolipile (figure 4-1), is mentioned in sources dating back as far as 250 B.C.

Throughout the course of history examples exist of other scientists using the principle of expanding gases to perform work. Among these were inventions of Leonardo da Vinci

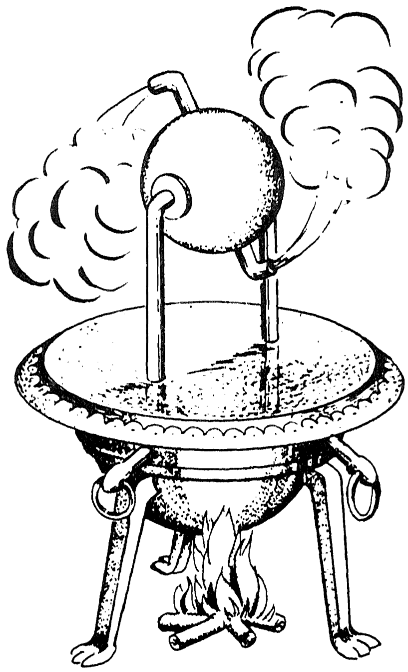

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Figure 4-1.—Hero's aeolipile.

(figure 4-2) and Giovanni Branca (figure 4-3).

In the 1680s Sir Isaac Newton described the laws of motion. All devices that use the theory of jet propulsion are based on these laws. Newton's steam wagon is an example of the reaction principle (figure 4-4).

The first patent for a design that used the thermodynamic cycle of the modern gas turbine was submitted in 1791. John Barber, an Englishman, submitted the patent. It was also suggested as a means of jet propulsion.

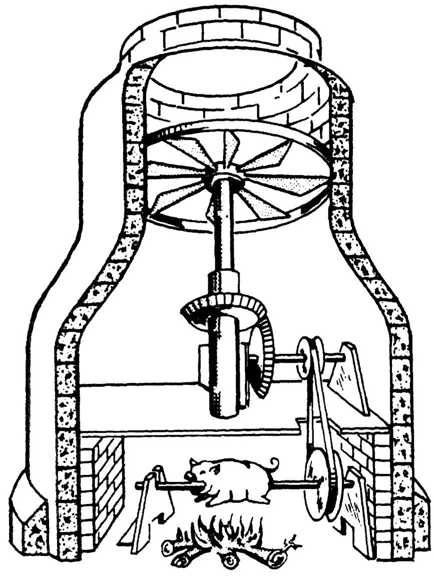

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Figure 4-2.—da Vinci's chimney jack.

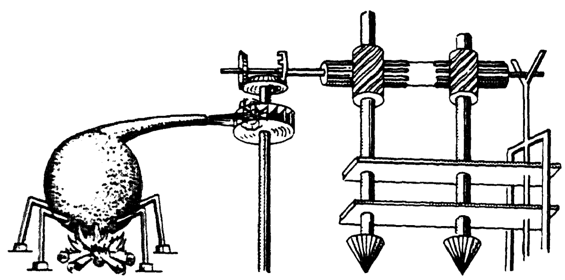

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Figure 4-3.—Branca's jet turbine.

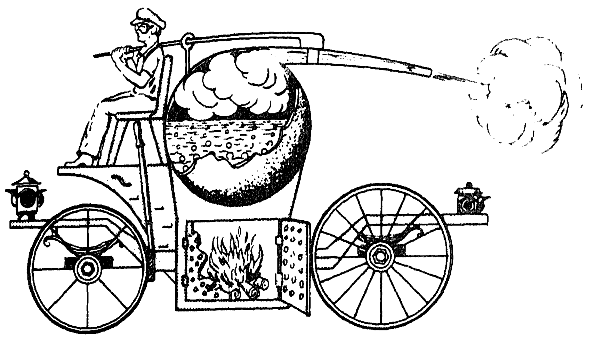

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Figure 4-4.—Newton's steam wagon.

TWENTIETH CENTURY DEVELOPMENT

The patented application for the gas turbine as we know it today was submitted in 1930 by another Englishman, Sir Frank Whittle. His patent was for a jet aircraft engine. Whittle used his own ideas along with the contributions of scientists such as Coley and Moss. After several failures, he came up with a working gas turbine engine (GTE). Up to this time the early pioneers in the gas turbine field were European born or oriented.

American Development

The United States did not go into the gas turbine field until late in 1941. General Electric was then awarded a contract to build an American version of a foreign-designed aircraft engine. The engine and airframe were both built in 1 year. The first jet aircraft was flown in this country in October 1942.

In late 1941 Westinghouse Corporation was awarded a contract to design and build the first all-American GTE. Their engineers designed the first axial flow compressor and annular combustion chamber. Both of these ideas, with minor changes, are the basis for the majority of contemporary engines in use today.

Marine Gas Turbines

The concept of using a gas turbine to propel a ship goes back to 1937. At that time a Pescara free piston gas engine was used experimentally with a gas turbine. The free piston engine, or gasifier (figure 4-5), is a form of diesel engine. It uses air cushions instead of a crankshaft to return the pistons. It was an effective producer of pressurized gases. The German navy used it in their submarines during World War II as an air compressor. In 1953 the French placed in service two small vessels powered by a free piston engine-gas turbine combination. In 1957 the liberty ship *William Patterson* went into service on a transatlantic run. It had six free piston engines driving two turbines.

At that time applications of the use of a rotary gasifier to drive a main propulsion turbine were used. The gasifier, or compressor, was usually an aircraft jet engine or turboprop front end. In 1947 the Motor Gun Boat 2009 of the British navy used a 2500-hp gas turbine. It was used to drive the center of three shafts. In 1951 the tanker *Auris*, in an experimental application, replaced one of four diesel engines with a 1200-hp gas turbine. In 1956 the *John Sergeant* had a very efficient installation. It gave a fuel consumption rate of .523 pounds per hp/hr. The efficiency was largely due to use of a regenerator which recovered heat from the exhaust gases.

By the late 1950s the gas turbine marine engine was becoming widely used, mostly by European navies. All the applications combined the gas turbine plant with another conventional form of propulsion machinery. The gas turbine was used for high-speed operation. The conventional plant was used for cruising. The most common arrangements were the Combined Diesel or Gas (CODOG) or the Combined Diesel and Gas (CODAG) Systems. Diesel engines give good cruising range and reliability. But they have a disadvantage when used in antisubmarine warfare. Their low-frequency sounds travel great distances through water. This makes them easily detected by passive sonar. Steam turbines have been combined to reduce low-frequency sound in the Combined Steam and Gas (COSAG) configuration like those used on the British County class destroyers. However, these require more personnel to operate. Also they do not have the long range of the diesel combinations. Another configuration that has been successful is the Combined Gas or Gas (COGOG) such as used on the British type 42 DDG. These ships use the 4500-hp Tyne GTE for cruising. They use the Rolls Royce Olympus, a 28,000-hp engine, for high speed.

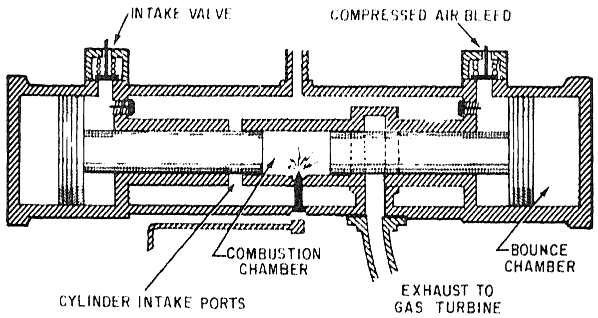

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Figure 4-5.—Free piston engine.

The U.S. Navy entered the marine gas turbine field with the *Asheville* class patrol gunboats. These ships have the CODOG configuration with two diesel engines for cruising. A General Electric LM1500 gas turbine operates at high speed. The Navy has now designed and is building destroyers, frigates, cruisers, and patrol hydrofoils that are entirely propelled by GTEs. This is a result of the reliability and efficiency of the new gas turbine designs.

ADVANTAGES AND DISADVANTAGES

The gas turbine, when compared to other types of engines, offers many advantages. Its greatest asset is its high power-to-weight ratio. This has made it, in the forms of turboprop or turbojet engine, the preferred engine for aircraft. Compared to the gasoline piston engine, the gas turbine operates on cheaper and safer fuel. The gasoline piston engine has the next best power-to-weight characteristics. The smoothness of the gas turbine, compared with reciprocating engines, has made it even more desirable in aircraft. Less vibration reduces strains on the airframe. In a warship, the lack of low-frequency vibration of gas turbines makes them preferable to diesel

engines. There is less noise for a submarine to pick up at long range. Modern production techniques have made gas turbines economical in terms of horsepower-per-dollar on initial installation. Their increasing reliability makes them a cost-effective alternative to steam turbine or diesel engine installation. In terms of fuel economy, modern marine gas turbines can compete with diesel engines. They may be superior to boiler/steam turbine plants, when these are operating on distillate fuel.

However, there are some disadvantages to gas turbines. Since they are high-performance engines, many parts are under high stress. Improper maintenance and lack of attention to details of procedure will impair engine performance. This may ultimately lead to engine failure. A pencil mark on a compressor turbine blade or a fingerprint can cause failure of the part. The turbine takes in large quantities of air which may contain substances or objects that can harm. Most gas turbine propulsion control systems are very complex because you have to control several factors. You have to monitor numerous operating conditions and parameters. The control systems must react quickly to turbine operating conditions to avoid casualties to the equipment. Gas turbines produce high-pitched loud noises which can damage the human ear. In shipboard installations special soundproofing is necessary. This adds to the complexity of the installation and makes access for maintenance more difficult. Also, the large amount of air used by a GTE requires large intake and exhaust ducting. This takes up much valuable space on a small ship.

From a tactical standpoint, there are two major drawbacks to the GTE. The first is the large amount of exhaust heat produced by the engines. Most current antiship missiles are heat-seekers. The infrared (IR) signature of a gas turbine makes an easy target. Countermeasures such as exhaust gas cooling and IR decoys have been developed to reduce this problem.

The second tactical disadvantage is the requirement for depot maintenance and repair of major casualties. The turbines are not overhauled in place on the ship. They must be removed and replaced by rebuilt engines if any major casualties occur. Here too, design has reduced the problem. An engine can be changed wherever crane service and the replacement engine are available.

FUTURE TRENDS

As improved materials and designs permit operation at higher combustion temperatures and pressures, gas turbine efficiency will increase. Even now, gas turbine main propulsion plants offer fuel economy and installation costs no greater than diesel engines. Initial costs are lower than equivalent steam plants which burn distillate fuels. Future improvements have made gas turbines the best choice for nonnuclear propulsion of ships up to cruiser size.

At present, marine gas turbines use aircraft jet engines for GGs. These are slightly modified for use in a marine environment, particularly in respect to corrosion resistance. As marine gas turbines become more widely used, specific designs for ships may evolve. These compressors may be heavier and bulkier than aircraft engines and take advantage of regenerators to permit greater efficiency.

Probably large gas turbines cannot be made simple enough to overhaul in place. So they will require technical support from shore. However, it is possible to airlift replacement engines. Gas turbine ships can operate and be repaired worldwide on a par with their steam- or diesel-driven counterparts.

The high power-to-weight ratios of GTEs permit the development of high-performance craft such as hydrofoils and surface effect vehicles. These crafts have high speed and are able to carry formidable weapons systems. They are being seen in increasing numbers in our fleet. In civilian versions, hydrofoils have been serving for many years to transport people on many of the world's waterways. Hovercraft are finding increased employment as carriers of people. They are capable of speeds up to 100 knots. If beach gradients are not too steep, they can reach points inland, marshy terrain, or almost any other level area.

GAS TURBINE OPERATION

A gas turbine engine is composed of three major sections:

1. Compressor(s)
2. Combustion chamber(s)
3. Turbine wheel(s)

A brief description of what takes place in a GTE during operation follows (figure 4-6). Air is taken in through the air inlet duct by the compressor which compresses the air and thereby raises pressure and temperature. The air is then discharged into the combustion chamber(s) where fuel is admitted by the fuel nozzle(s). The fuel-air mixture is ignited by igniter(s) and combustion takes place. Combustion is continuous, and the igniters are de-energized after a brief period of time. The hot and rapidly expanding gases are directed toward the turbine rotor assembly. Kinetic and thermal energy are extracted by the turbine wheel(s). The action of the gases against the turbine blades causes the turbine assembly to rotate. The turbine rotor is connected to the compressor which rotates with the turbine. The exhaust gases then are discharged through the exhaust duct.

About 75 percent of the power development by a GTE is used to drive the compressor and accessories. Only 25 percent can be used to drive a generator or to propel a ship.

LAWS AND PRINCIPLES

To understand basic engine theory, you must be familiar with the physics concepts used in the operation of a GTE. In the following paragraphs we will discuss the laws and principles that will apply to your work. We will define them, explain them, and then demonstrate how they apply to a gas turbine.

BERNOULLI'S PRINCIPLE: If an incompressible fluid flowing through a tube reaches a constriction, or narrowing of the tube, the velocity of fluid flowing through the constriction increases and the pressure decreases.

BOYLE'S LAW: The volume of an enclosed gas varies inversely with the applied pressure, provided the temperature remains constant.

CHARLES' LAW: If the pressure is constant, the volume of an enclosed dry gas varies directly with the absolute temperature.

NEWTON'S LAW: The first law states that a body at rest tends to remain at rest. A body in motion tends to remain in motion. The second law states that an imbalance of force on a body tends to produce an acceleration in the direction of the force. The acceleration, if any, is directly proportional to the force and inversely

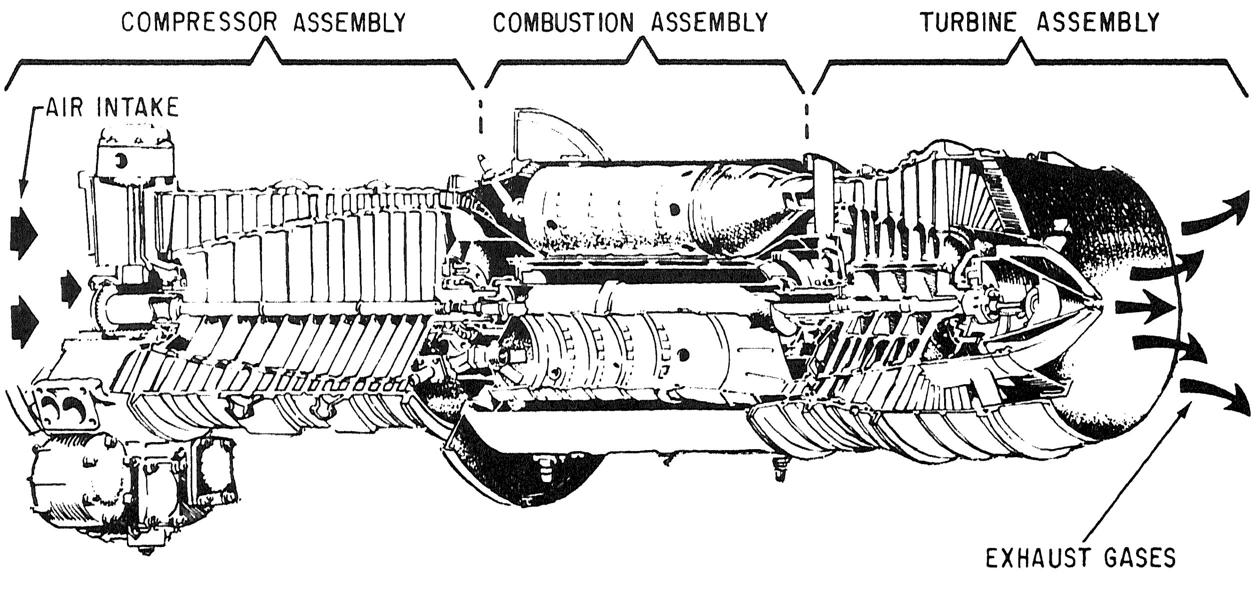

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Figure 4-6.—Gas turbine operation.

proportional to the mass of the body. Newton's third law states that for every action there is an equal and opposite reaction.

PASCAL'S LAW: Pressure exerted at any point upon an enclosed liquid is transmitted undiminished in all directions.

BERNOULLI'S PRINCIPLE

Consider the system illustrated in figure 4-7. Chamber A is under pressure and is connected by a tube to chamber B which is also under pressure. Chamber A is under static pressure of 100 psi. The pressure at some point, (X), along the connecting tube consists of a velocity pressure of 10 psi. This is exerted in a direction parallel to the line of flow. Added is the unused static pressure of 90 psi, which obeys Pascal's law and operates equally in all directions. As the fluid enters chamber B from the constricted space, it is slowed down. In so doing, its velocity head is changed back to pressure head. The force required to absorb the fluid's inertia equals the force required to start the fluid moving originally. Therefore, the static pressure in chamber B is again equal to that in chamber A. It was lower at intermediate point X.

The illustration (figure 4-7) disregards friction and is not encountered in actual practice. Force or head is also required to overcome friction. But, unlike inertia effect, this force cannot be recovered again although the energy represented still exists somewhere as heat. Therefore, in an actual system the pressure in chamber B would be less than in chamber A. This is a result of the amount of pressure used in overcoming friction along the way.

At all points in a system the static pressure is always the original static pressure LESS any velocity head at the point in question. It is also LESS the friction head consumed in reaching that point. Both velocity head and friction represent energy that came from the original static head. Energy cannot be destroyed. So, the sum of the static head, velocity head, and friction at any point in the system must add up to the original static head. This, then, is Bernoulli's principle, more simply stated: If a noncompressible fluid flowing through a tube reaches a constriction, or narrowing of the tube, the velocity of fluid flowing through the constriction increases, and the pressure decreases. Bernoulli's principle governs the relationship of the static and dynamic factors concerning noncompressible fluids. Pascal's law governs the behavior of the static factors when taken by themselves.

BOYLE'S LAW

Compressibility is an outstanding characteristic of gases. The English scientist, Robert Boyle, was among the first to study this characteristic. He called it the springiness of air. He discovered that when the temperature of an enclosed sample of gas was kept constant and the pressure doubled, the volume was reduced to half the former value. As the applied pressure was decreased, the resulting volume increased. From these observations he concluded that for a constant temperature the product of the volume and pressure of an enclosed gas remains constant. This became Boyle's law, which is normally

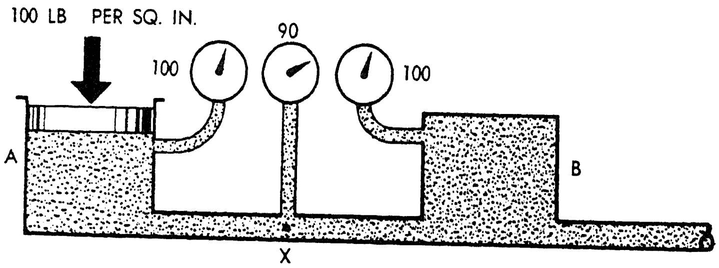


Figure 4-7.—Relation of static and dynamic factors—Bernoulli's principle. 194.32

stated: The volume of an enclosed dry gas varies inversely with its pressure, provided the temperature remains constant.

You can demonstrate Boyle's law by confining a quantity of gas in a cylinder which has a tightly fitted piston. Then apply force to the piston so as to compress the gas in the cylinder to some specific volume. If you double the force applied to the piston, the gas will compress to one half its original volume (figure 4-8).

In formula or equation form (V = volume; P = pressure) when V_1 and P_1 are the original volume and pressure and V_2 and P_2 are the revised volume and pressure, this relationship may be expressed

$$V_1P_1 = V_2P_2$$

or

$$\frac{V_1}{V_2} = \frac{P_2}{P_1}$$

Example: 4 cubic feet of nitrogen are under a pressure of 100 psig. The nitrogen is allowed to expand to a volume of 6 cubic feet. What is the new gauge pressure? Remember to convert gauge pressure to absolute pressure by adding 14.7.

$$V_1P_1 = V_2P_2$$

Substitute

$$4 \times (100 + 14.7) = 6 \times P_2$$

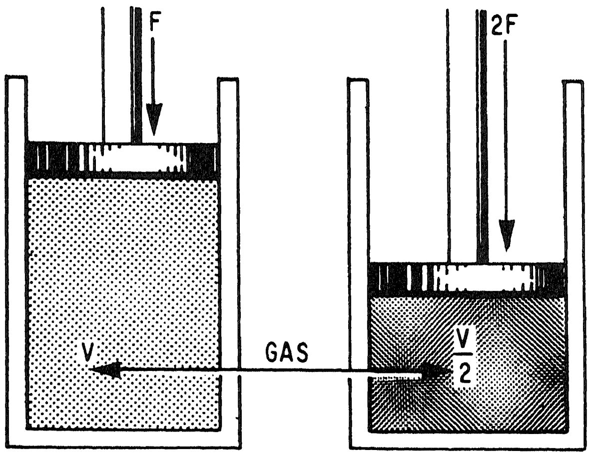
$$P_2 = \frac{4 \times 114.7}{6}$$

$$P_2 = 76.47 \text{ psia}$$
(absolute pressure)

Convert absolute pressure to gauge pressure

$$\begin{array}{r} 76.47 \\ -14.7 \\ \hline 61.77 \end{array}$$ psig (gauge pressure)

Changes in the pressure of a gas also affect the density. As the pressure increases, its volume decreases; however, there is no change in the weight of the gas. Therefore, the weight per unit volume (density) increases. So it follows that the density of a gas varies directly as the pressure, if the temperature is constant.



194.9

Figure 4-8.—Gas compressed to half its original volume by a double force.

CHARLES' LAW

Jacques Charles, a French scientist, provided much of the foundation for the modern kinetic theory of gases. He found that all gases expand and contract in direct proportion to the change in the absolute temperature. This is provided the pressure is held constant. In equation form where V_1 and V_2 refer to the original and final volumes, and T_1 and T_2 indicate the corresponding absolute temperatures, this part of the law may be expressed

$$V_1T_2 = V_2T_1$$

or

$$\frac{V_1}{V_2} = \frac{T_1}{T_2}$$

Any change in the temperature of a gas causes a corresponding change in volume. Therefore, if a given sample of a gas were heated while confined within a given volume, the pressure should increase. Actual experiments found that for each

1 °C increase in temperature, the increase in pressure was about $\frac{1}{273}$ of the pressure at 0 °C. Thus, it is normal practice to state this relationship in terms of absolute temperature. In equation form, this part of the law becomes

$$P_1T_2 = P_2T_1$$

or

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

In words, this equation states that with a constant volume, the absolute pressure of an enclosed gas varies directly with the absolute temperature.

Examples of Charles' law: A cylinder of gas under a pressure of 1800 psig at 20 °C is left out in the sun. It heats up to a temperature of 55 °C. What is the new pressure within the cylinder? (You must convert the pressure and temperature to absolute pressure and temperature.)

$$\frac{P_1}{P_2} = \frac{T_1}{T_2}$$

or

$$\frac{1814.7\ \text{psia}}{2031.47\ \text{psia}} = \frac{293\ ^\circ\text{C absolute}}{328\ ^\circ\text{C absolute}}$$

NEWTON'S FIRST LAW

Newton's first law states that a body at rest tends to remain at rest. A body in motion tends to remain in motion. This law can be demonstrated easily in everyday use. For example, a parked automobile will remain motionless until some force causes it to move—a body at rest tends to remain at rest. The second portion of the law—a body in motion tends to remain in motion—can be demonstrated only in a theoretical sense. The same car placed in motion would remain in motion (1) if all air resistance were removed, (2) if no friction were in the bearings, and (3) if the surface were perfectly level.

NEWTON'S SECOND LAW

Newton's second law states that an imbalance of force on a body tends to produce an acceleration in the direction of the force. The acceleration, if any, is directly proportional to the force. It is inversely proportional to the mass of the body. This law can be explained by throwing a common softball. The force required to accelerate the ball to a rate of 50 ft/sec^2 would have to be doubled to obtain an acceleration rate of 100 ft/sec^2. However, if the mass of the ball were doubled, the original acceleration rate would be cut in half. You would have 50 ft/sec^2 reduced to 25 ft/sec^2. Do not confuse mass with weight. This law can be explained mathematically (A = acceleration; F = force; M = mass)

$$A = \frac{F}{M}$$

NEWTON'S THIRD LAW

Newton's third law states that for every action there is an equal and opposite reaction. You have demonstrated this law if you have ever jumped from a boat up to a dock or a beach. The boat moved opposite to the direction you jumped (figure 4-9).

The recoil from firing a shotgun is another example of action-reaction. We can demonstrate this law with the same factors used in the second law in the equation

$$F = MA$$

In an airplane, the greater the mass of air handled by the engine, the more it is accelerated by the engine. The force built up to thrust the plane forward is also greater. In a gas turbine, the thrust velocity can be absorbed by the turbine rotor and converted to mechanical energy. This is done by adding more and progressively larger PT wheels.

BASIC ENGINE THEORY

Two factors are required for proper operation of a gas turbine. One is expressed by Newton's third law. The other is the convergent-divergent

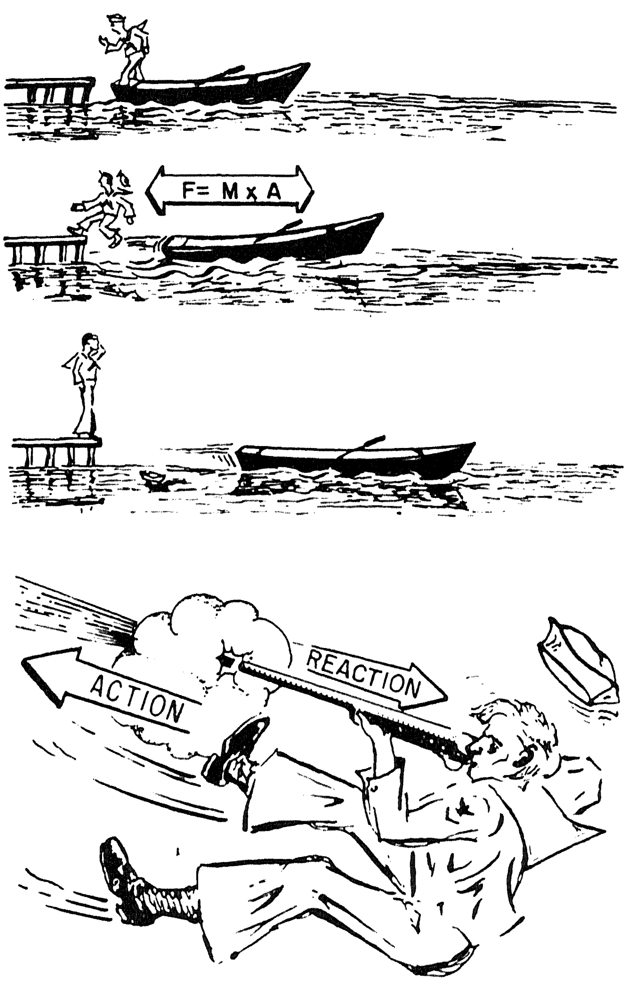


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Figure 4-9.—Newton's third law of motion.

process. Convergent means approaching nearer together, as the inner walls of a tube that is constricted. Divergent means moving away from each other, as the inner walls of a tube that flares outward.

Bernoulli's principle is used in this process. The venturi of the common automobile carburetor is a common example of Bernoulli's principle and the convergent-divergent process. The following is a description of a practical demonstration of how a gas turbine operates. (See figure 4-10, a foldout at the end of this chapter.)

A blown-up balloon (figure 4-10, item A) does nothing until the trapped air is released. The air escaping rearward causes the balloon to move forward (Newton's third law) (figure 4-10, item B).

If you could keep the balloon full of air, the balloon would continue to move forward (figure 4-10, item C).

If a fan or pinwheel is placed in the air stream, the pressure energy and velocity energy will cause it to rotate. It can then be used to do work (figure 4-10, item D).

Replace the balloon with a tube or container (mounted in one place). Fill it with air from a fan or series of fans. They should be located in the air opening and driven by some source. You use the discharge air to turn a fan at the rear to do work (figure 4-10, item E).

If fuel is added and combustion occurs, both the volume of air (Charles' law) and the velocity with which it passes over the fan are greatly increased. The horsepower the fan will produce is also increased (figure 4-10, item F).

The continuous pressure created by the inlet fan, or compressor, prevents the hot gases from going forward.

Next, if you attach a shaft to the compressor and extend it back to a turbine wheel, you have a simple gas turbine. It can supply power to run its own compressor and still provide enough power to do useful work. It could drive a generator or propel a ship (figure 4-10, item G).

By comparing figure 4-10, item H, with figure 4-10, item G, you can see that a gas turbine is very similar to the balloon turbine. Recall the three basic parts of a gas turbine mentioned earlier.

1. Air is taken in through the air inlet duct by the compressor. There it is raised in pressure and discharged into the combustion chamber.
2. Fuel is admitted into the combustion chamber by the fuel nozzle(s). The fuel-air mixture is ignited by igniter(s) and combustion occurs.
3. The hot and rapidly expanding gases are directed aft through the turbine rotor assembly. There thermal and kinetic energy are converted into mechanical energy. The gases are then directed out through the exhaust duct.

THEORETICAL CYCLES

Before we go into construction and design, we will discuss a little more on cycles and theory.

A cycle is a process that begins with certain conditions. It progresses through a series of additional conditions and returns to the original conditions.

The GTE operates on the BRAYTON CYCLE. The Brayton cycle is one where combustion occurs at constant pressure. In gas turbines specific components are designed to perform each function separately. These functions are intake, compression, combustion, expansion, and exhaust.

The Brayton cycle can also be graphically explained (figure 4-11). Air enters the inlet at atmospheric pressure and constant volume (point A). As the air passes through the compressor, it increases in pressure and decreases in volume (line A-B). At point B combustion occurs at constant pressure while the increased temperature causes a sharp increase in volume (line B-C). The gases at constant pressure and increased volume enter the turbine and expand through it. As the gases pass through the turbine rotor, the rotor turns kinetic and thermal energy into mechanical energy. The expanding size of the passages causes further increase in volume and a sharp decrease in pressure (line C-D). The gases are released through the stack with a large drop in volume and at constant pressure (line D-A). The cycle is continuous in a GTE, with each action occurring at all times.

OPEN AND CLOSED CYCLES

Most internal-combustion engines operate on an open engine cycle. This means the working fluid is taken in, used, and discarded. There are some gas turbines that operate on a semiclosed cycle. They use a regenerator such as used on the gas turbine ship *John Sergeant*. The gas turbines you will encounter in the Navy operate on the open cycle.

In the open cycle all the working fluid passes through the engine only once. The open cycle offers the advantages of simplicity and light weight.

The third classification of cycles is the closed cycle, where energy is added externally. The typical ship's steam plant is an example of a closed cycle system.

CONVERGENT-DIVERGENT PROCESS

There are several pressure, volume, and velocity changes that occur within a gas turbine during operation. The convergent-divergent process is an application of Bernoulli's principle. (If a fluid flowing through a tube reaches a constriction or narrowing of the tube, the velocity of the fluid flowing through the constriction increases and the pressure decreases. The opposite is true when the fluid leaves the constriction; velocity decreases and pressure increases.) Boyle's law and Charles' law also come into play during this process. Boyle's law: The volume of any dry gas varies inversely with the applied pressure, provided the temperature remains constant. Charles' law: If the pressure is constant, the volume of dry gas varies directly with the absolute temperature.

Now, let's apply these laws to the gas turbine. Refer to figure 4-12.

Air is drawn into the front of the compressor. The rotor is so constructed that the area decreases toward the rear. This tapered construction gives a convergent area (area A). Each succeeding stage is smaller, which increases pressure and decreases velocity (Bernoulli).

Between each rotating stage is a stationary stage or stator. The stator partially converts high velocity to pressure and directs the air to the next set of rotating blades.

Because of its high rotational speed, the rotor imparts velocity to the air. Each pair of rotor and stator blades constitutes a pressure stage. Also, there is both a pressure increase at each stage and a reduction in volume (Boyle).

This process continues at each stage until the air charge enters the diffuser (figure 4-12, area B). There is a short area in the diffuser where no further changes take place. As the air charge approaches the end of the diffuser, you will notice that the opening flares (diverges) outward. At this point, the air loses velocity and increases in volume and pressure. Thus, the velocity energy has become pressure energy, while pressure through the diffuser has remained constant. The reverse of Bernoulli's principle and Boyle's law has taken place. The compressor continuously forcing more air through this section at a constant rate maintains constant pressure. Once the air is in the combustor, combustion takes place

at constant pressure. After combustion there is a large increase in the volume of the air and combustion gases (Charles' law).

The combustion gases go rearward to area C. This occurs partially by velocity imparted by the compressor and partially because area C is a lower pressure area. The end of area C is the turbine nozzle section. Here you will find a decrease in pressure and an increase in velocity. The high-velocity, high-temperature, low-pressure gases are directed through the inlet nozzle to the first stage of the turbine rotor (area D). The high-velocity, high-temperature gases cause the rotor to rotate by transferring velocity energy and thermal energy to the turbine blades. Area D is a divergent area. Between each rotating turbine stage is a static stage or nozzle. The nozzles act much the same as the stators in the compressor.

A nozzle is a stator ring with a series of vanes. They act as small nozzles to direct the combustion gases uniformly and at the proper angle to the turbine blades. Due to the design of the nozzles, each succeeding stage imparts velocity to the gases as they pass through the nozzle. Each nozzle converts heat and pressure energy into velocity energy by controlling the expansion of the gas. Each small nozzle has a convergent area.

Each stage of the turbine is larger than the preceding one. The pressure energy drops are quite rapid; consequently, each stage must be larger to use the energy of a lower pressure, lower temperature, and larger volume of gases. If more stages are used the rate of divergence will be less. Area D must diverge rapidly in proportion to the rate in which area A converges into area B. Atmospheric air is raised in pressure and velocity and lowered in volume in area A by the

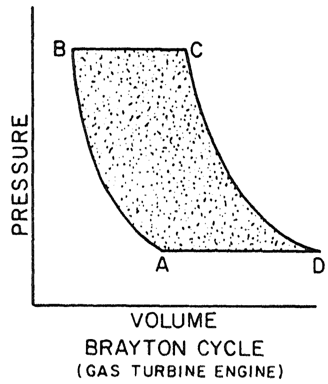

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Figure 4-11.—The Brayton cycle.

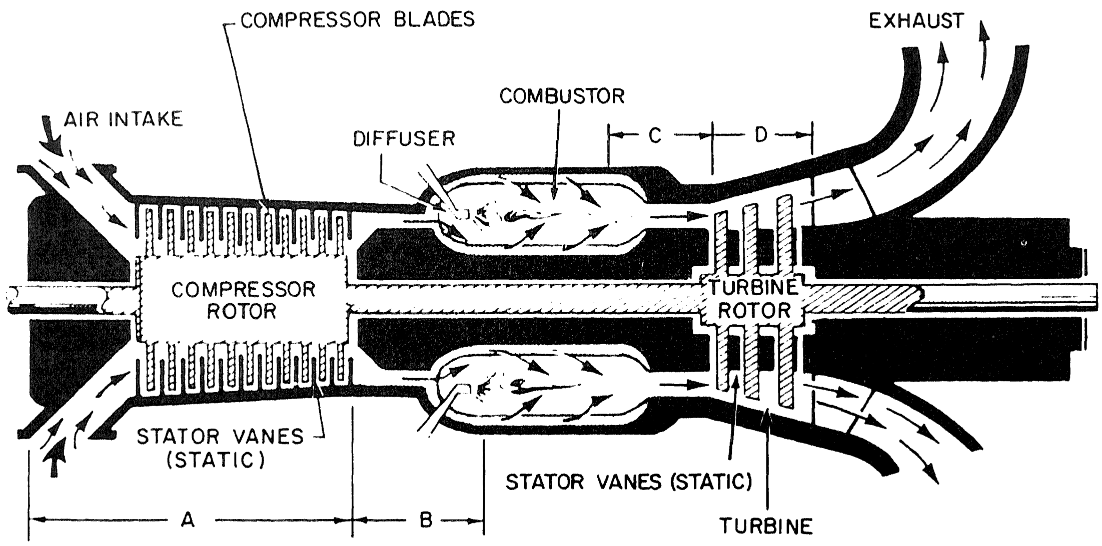

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Figure 4-12.—Convergent-divergent process.

compressor. Each stage can only compress air about 1.2 times, so the rate is limited. However, in the turbine rotor (area D), the gases give up thermal and pressure energy and increase in volume through three stages. (If this did not happen rapidly, back pressure from area D would cause area C to become choked.) The gases in the combustor would back up into the compressor. There they would disrupt airflow and cause a condition known as surge, or compressor stall. This condition can destroy an engine in a matter of seconds. Surge will be explained later in our discussion of axial flow compressors (stators).

The gases from the last turbine stage enter the exhaust duct where they are transmitted to the atmosphere. The leading portion of the exhaust duct is part of a divergent area. Further divergence reduces the pressure and increases the volume of the warm gases and aids in lowering the velocity. The exhaust gases enter the atmosphere at or slightly above atmospheric pressure. This depends on the length and size of the exhaust duct.

Now refer back to figure 4-11. Air enters the intake at constant pressure (point A). It is compressed as it passes through the compressor (line A-B in figure 4-11 and area A in figure 4-12). Between the end of area B and the beginning of area C in figure 4-12, combustion occurs and volume increases (figure 4-11, line B-C). As the gases pass through area D (figure 4-12), the gases expand with a drop in pressure and an increase in volume (figure 4-11, line C-D). The gases are discharged to the atmosphere through the exhaust duct at constant pressure (figure 4-11, line D-A and figure 4-12, exhaust). At this point you should have a clear understanding of how a simple gas turbine works.

ADIABATIC COMPRESSION

In the ideal gas turbine, the air enters the compressor and is compressed adiabatically. In an adiabatic stage change there is no transfer of heat to or from the system during the process. In many real processes, adiabatic changes can occur when the process is performed rapidly. Since heat transfer is relatively slow, any rapidly performed process can approach an adiabatic state. Compression and expansion of working fluids are often achieved almost adiabatically.

Figure 4-13 depicts the pressure-temperature graph for a simple gas turbine. During operation the work produced by the compressor turbine rotor is almost the same amount as the work required by the compressor. The mass flow available to the compressor turbine is about the same as the mass flow handled by the compressor. Therefore, the heat of compression will closely equal the heat of expansion. Allowances are made for factors such as bleed air, pressure of fuel added, and heat loss to turbine parts.

As the high-temperature, high-pressure gases enter the turbine section, they expand rapidly. There is relatively little change in temperature of the gases. The net power available from the turbine is the difference between the turbine-developed power and the power required to operate the compressor.

EFFECT OF AMBIENT TEMPERATURE

The power and efficiency of a GTE are affected by both outside and inside variables. Air has volume that is directly affected by its temperature. As the temperature decreases, the volume of air for a given mass decreases and its density increases. Consequently, the mass weight of the air increases which, in turn, increases efficiency. This happens because less energy is needed to achieve the same compression at the combustion chambers. Also cooler air causes lower burning temperatures. The resulting

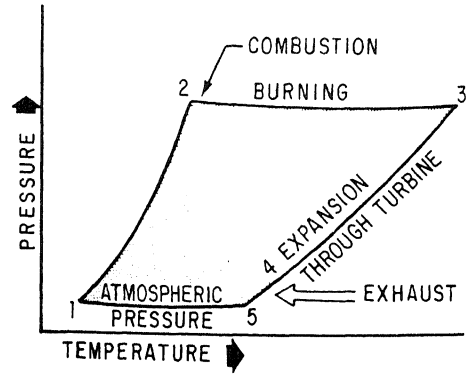

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Figure 4-13.—Gas turbine pressure-temperature relationship.

temperatures extend turbine life. For example, a propulsion gas turbine is operating at 100 percent GG speed with 100 percent PT speed. The ambient (external air) temperature is 70 °F. If the temperature were increased to 120 °F, the volume of air would increase. The mass weight would decrease. Since the amount of fuel added is limited by the inlet temperature the turbine will withstand, the mass weight flow cannot be achieved; the result is a loss of net power available for work. The plant may be able to produce only 90 to 95 percent of its rated horsepower.

On the other hand, if the ambient temperature were to drop to 0 °F, the volume of air would decrease. The mass weight would increase. Since the mass weight is increased and heat transfer is better at higher pressure, less fuel is needed to increase volume; the result is a heavier mass of air at the required volume. This situation produces quite an efficient power plant. It has a GG speed of 85 to 90 percent and a PT speed of 100 percent. In the case of a constant speed engine, the differences in temperature will show up on exhaust gas temperature. In some cases, it will show up on the load the engine will pull. For instance, on a hot day of 120 °F, the engine on a 300-kW generator set may be able to pull only 275 kW. This is due to limitations on exhaust or turbine inlet temperature. On a day with 0 °F ambient temperature, the same engine will pull 300-kW. It can have an exhaust or turbine inlet temperature that is more than 100 °F, lower than average. Here again, less fuel is needed to increase volume and a greater mass weight flow. In turn, the plant is more efficient.

COMPRESSOR CLEANLINESS

Another factor that will have a great effect on performance is the condition of the compressor. A clean compressor is essential to efficiency and reliability. During operation at sea the compressor will ingest salt spray. Over a period of time, this salt will build up in the compressor. Salt buildup is relatively slow. It will occur more on the stator vanes and the compressor case than on rotating parts. Centrifugal force tends to sling salt contaminants off the rotor blades. Also, oil rapidly increases contamination of the compressor. Any oil ingested into the engine coats the compressor with a film. The film traps any dust and other foreign matter suspended in the air. The dust and dirt absorb more oil which traps more dirt, and so forth. If left unattended, the buildup of contamination will lead to a choking of the compressor and a restricted airflow. In turn, gradually more fuel is required. So the gas temperatures will rise until loss of power and damage to the turbine may result. Contamination, if not controlled, can lead to a compressor surge during engine start. It will also reduce the life of the compressor and turbine blading.

TYPES OF GAS TURBINE ENGINES

There are several different types of gas turbines, all using the same basic principles already discussed. GTEs are classified by their construction (the type of compressor, combustor, or its shafting). The compressor may be either centrifugal or axial type. The combustor may be annular, can-annular, or can type. The type of shaft used on a GTE is also used to classify an engine. The three types are single shaft, split shaft, or twin spool. These classifications will be discussed on the following pages.

CLASSIFICATION BY COMPRESSOR TYPE

Gas turbines may be classified by compressor type, according to the direction of the flow of air through the compressor. The two principal types are centrifugal flow and axial flow. The centrifugal compressor draws in air at the center or eye of the impeller and accelerates it around and outward. In the axial flow engine the air is compressed while continuing its original direction of flow. The flow of air is parallel to the axis of the compressor rotor.

Centrifugal Compressor

The centrifugal compressor is usually located between the accessory section and the combustion section. The basic compressor section consists of an impeller, diffuser, and compressor manifold. The diffuser is bolted to the manifold. Often the entire assembly is referred to as the diffuser. For ease of understanding, we shall treat each unit separately.

The impeller may be either single entry or dual entry (figure 4-14). The main differences between the single entry and dual entry are the size of the impeller and the ducting arrangement. The single entry impeller permits convenient ducting directly to the inducer vanes. The dual entry uses a more complicated ducting to reach the rear side. Single entry impellers are slightly more efficient in receiving air. They must be of greater diameter to provide sufficient air which increases the overall diameter of the engine.

Dual entry impellers are smaller in diameter. They rotate at higher speeds to ensure sufficient airflow. Most gas turbines of present-day design use the dual entry compressor to reduce engine diameter. The air must enter the engine at almost right angles to the engine axis. Because of this a plenum chamber is also required for dual entry compressors. The air must surround the compressor at positive pressure before entering the compressor to give positive flow.

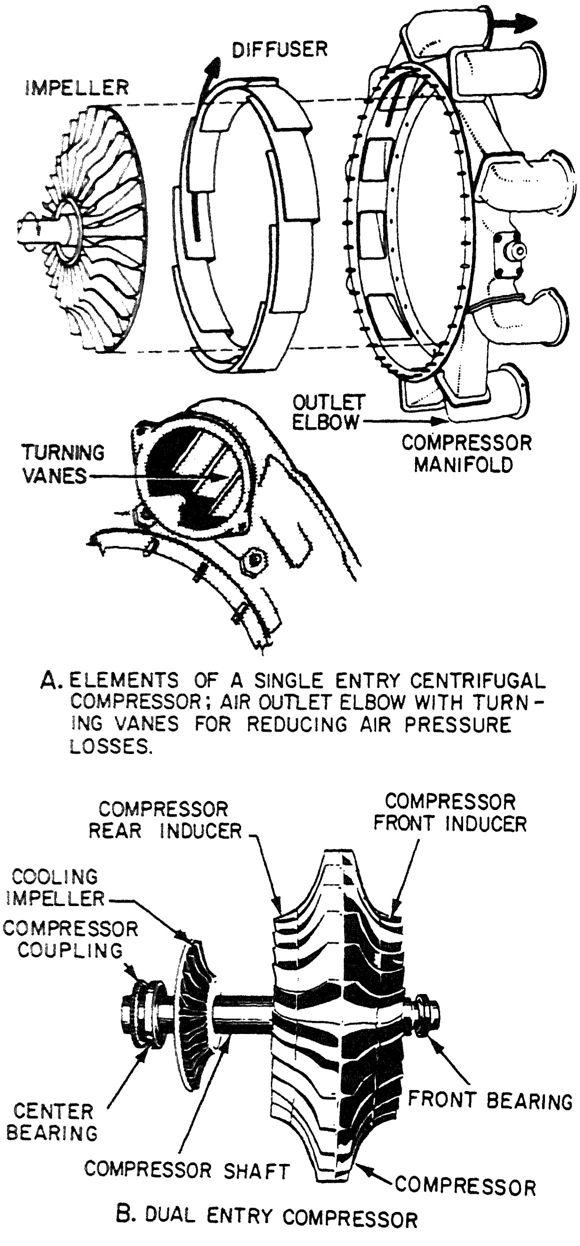

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Figure 4-14.—Centrifugal compressors.

PRINCIPLES OF OPERATION.—The compressor draws in the entering air at the hub of the impeller and accelerates it radially outward by means of centrifugal force through the impeller. It leaves the impeller at a high velocity low pressure and flows through the diffuser (figure 4-14, item A). The diffuser converts the high-velocity, low-pressure air to low velocity with high pressure. The compressor manifold diverts the flow of air from the diffuser, which is an integral part of the manifold, into the combustion chambers.

CONSTRUCTION.—In the centrifugal compressor the manifold has one outlet port for each combustion chamber. The outlet ports are bolted to an outlet elbow on the manifold (figure 4-14, item A). The outlet ports ensure that the same amount of air is delivered to each combustion chamber.

The outlets are known by a variety of names. Regardless of the names used, the elbows change the airflow from radial flow to axial flow. Then the diffusion process is completed after the turn. Each elbow contains from two to four turning vanes to efficiently perform the turning process. They also reduce air pressure losses by presenting a smooth turning surface.

The impeller is usually fabricated from forged aluminum alloy, heat-treated, machined, and smoothed for minimum flow restriction and turbulence. Some types of impellers are made from a single forging. In other types the inducer vanes are separate pieces.

Centrifugal compressors may achieve efficiencies of 80 to 84 percent at pressure ratios of 2.5:1 to 4:1 and efficiencies of 76 to 81 percent at pressure ratios of 4:1 to 10:1.

Advantages: rugged, simple in design, relatively light in weight, and develops high-pressure ratio per stage.

Disadvantages: large frontal area, lower efficiency, and difficulty in using two or more stages due to air loss that will occur between stages and seals.

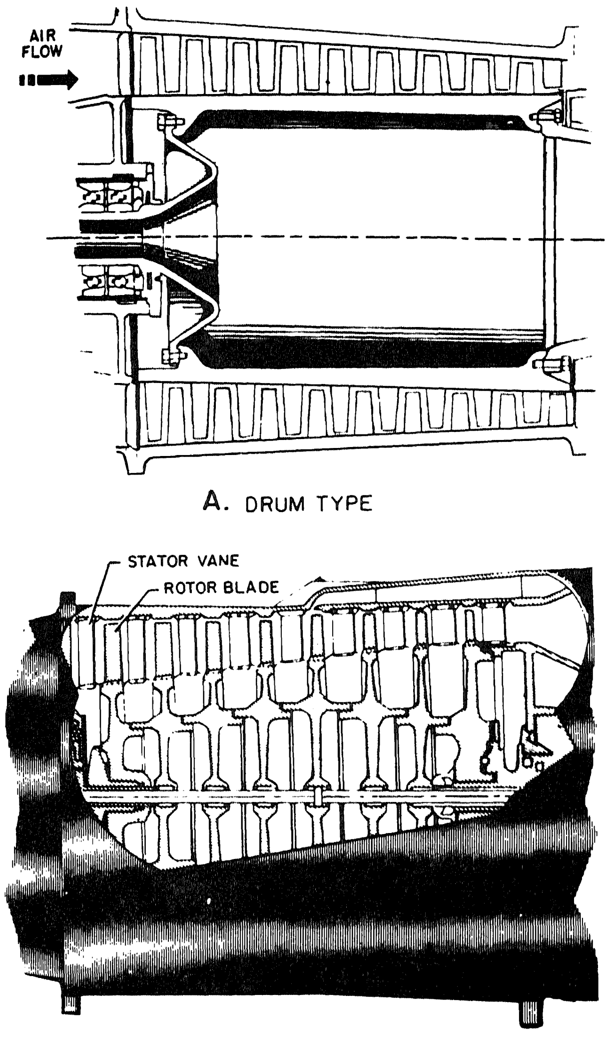

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Figure 4-15.—Compressor rotors.

Axial Flow Compressors

There are two main types of axial compressors (figure 4-15). One is the drum type and the other is the disk type.

The purpose of the axial compressor is the same as the centrifugal type. Both take in ambient air and increase the velocity and pressure. They discharge the air through the diffuser into the combustion chamber.

The two main elements of an axial flow compressor are the rotor and stator (figure 4-16).

The rotor has fixed blades which force the air rearward much like an aircraft propeller. Behind each rotor stage is a stator. The stator directs the air rearward to the next rotor stage. Each consecutive pair of rotor and stator blades constitutes a pressure stage.

The action of the rotor at each stage increases compression of the air at each stage and accelerates it rearward. By virtue of this

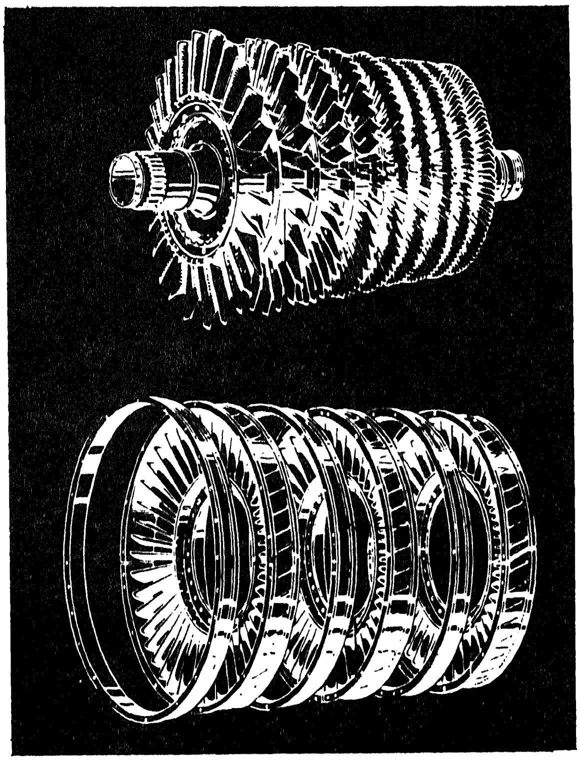

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Figure 4-16.—Rotor (top) and stator (bottom) components of an axial flow compressor.

increased velocity, energy is transferred from the compressor to the air in the form of velocity energy. The stators at each stage act as diffusers, partially converting high velocity to pressure.

The number of stages required is determined by the amount of air and total pressure rise required. The greater the number of stages, the higher the compression ratio. Most present-day engines have 8 to 16 stages, depending on air requirements.

COMPRESSOR CONSTRUCTION.—The rotor and stators are enclosed in the compressor case. Present-day engines use a case that is horizontally divided into upper and lower halves. The halves are normally bolted together with either dowel pins or fitted bolts. They are located at various points. They ensure proper alignment to each other and in relation to other engine assemblies. The other assemblies bolt to either end of the compressor case.

On some older design engines, the case is a one-piece cylinder open on both ends. The one-piece compressor case is simpler to manufacture; however, any repair or detailed inspection of the compressor rotor is impossible. The engine must be removed and taken to a shop. There it is disassembled for repair or inspection of the rotor or stators. On many engines with the split case, either the upper or lower case can be removed. The engine can remain in place for maintenance and inspection.

The compressor case is usually made of aluminum or steel. The material used will depend on the engine manufacturer and the accessories attached to the case. The compressor case may have external connections made as part of the case. These connections are normally used to bleed air during starting and acceleration or at low-speed operation.

Drum-Type Construction.—The drum-type rotor (figure 4-15, item A) consists of rings that are flanged to fit one against the other. The entire assembly may then be held together by through bolts. The drum is one diameter over its full length. The blades and stators vary in length from front to rear. The compressor case tapers accordingly. This type of construction is satisfactory for low-speed compressors where centrifugal stresses are low.

Disk-Type Construction.—The disk-type rotor (figure 4-15, item B) consists of a series of disks machined from aluminum forgings, shrunk over a steel shaft. Another method of rotor construction is to machine the disks and shaft from a single aluminum forging. Then bolt steel stub shafts on the front and rear of the assembly. This provides bearing support surfaces and splines for joining the turbine shaft. The blades vary in length from entry to discharge. This is due to a progressive reduction in the annular working space (drum to casing) toward the rear. The working space decreases because the rotor disk diameter increases. The disk-type rotors are used almost exclusively in all present-day, high-speed engines.

COMPRESSOR BLADING.—Each stage of an axial compressor consists of a set of rotor and stator blades. Stator blades may also be referred to as vanes. The construction of these blades is important to efficient operation of a gas turbine..

Rotor Blades.—The rotor blades are usually made of stainless or semistainless steel. Methods of attaching the blades in the rotor disk rims vary in different designs. They are commonly fitted into disks by either bulb (figure 4-17, item A) or fir-tree (figure 4-17, item B) type of roots. The blades are then locked by means of grub-screws, peening, lockwires, pins, or keys.

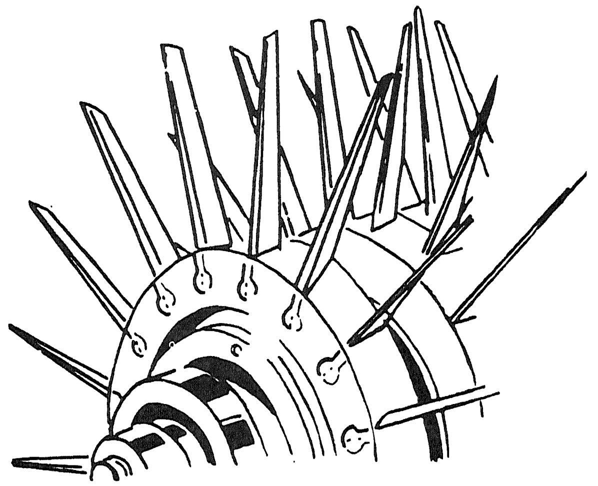
Compressor blade tips are reduced by cutouts, which are referred to as blade profiles. These profiles allow rubbing which occurs when rotor blades come into contact with the compressor or housing. This prevents serious damage to the blade or housing.

Some manufacturers use a ring that acts as a spacer for the stators. A ring can also act as a wear surface when the blade tips come into contact with the ring.

Another method of preventing excessive rubbing while maintaining minimum clearance is to metal-spray the case and stators. Thin squealer tips on the blades and vanes (figure 4-18) contact the sprayed material. The abrasive action of the blade tip prevents excessive rubbing while obtaining minimum clearance.

The primary causes of rubbing are an excessively loose blade or a malfunction of a compressor support bearing. This causes the compressor rotor to drop.

Large compressors have loose-fitting blades on the first several stages. These move during



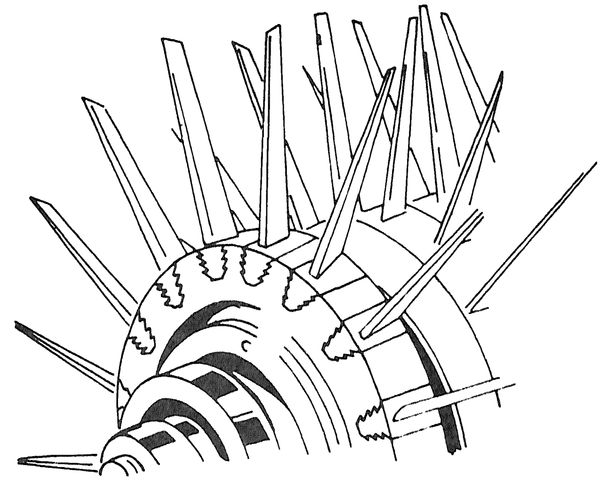


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Figure 4-17.—Rotor blades.

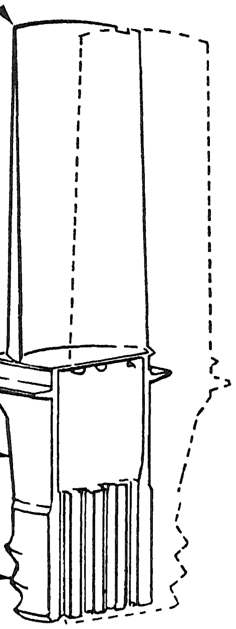

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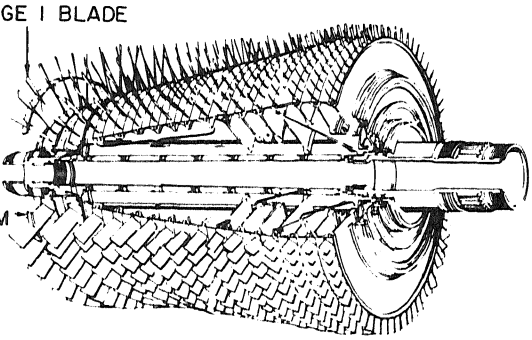
Figure 4-18.—Blade with squealer tip.



277.14

Figure 4-19.—Compressor rotor, LM2500 engine.

acceleration to minimize vibration while passing through critical speed ranges. Once up to speed, centrifugal force locks the blades in place and little or no movement occurs. There is also movement of the blades during rundown. On a clean engine some of the blades may have as much as 1/4-inch radial movement. You may hear a tinkling sound during rundown.

Large compressor rotors have long blades on the first stage. They have a piece made onto the blade called a midspan platform (figure 4-19). The platform gives some radial support to the blades during acceleration. Support is needed because of the length and amount of movement of the blades.

Stators.—The stator vanes project radially toward the rotor axis. They fit closely on either

side of each stage of the rotor. The function of the stators is twofold: (1) they receive air from the air inlet duct or from each preceding stage of the rotor. They then deliver the air to the next stage or to combustors at a workable velocity and pressure; (2) the stators also control the direction of air to each rotor stage to obtain the maximum possible compressor blade efficiency. The stator vanes are usually made of steel with corrosion- and erosion-resistant qualities. Frequently, the vanes are shrouded by a band of suitable material to simplify the fastening problem. The vanes are welded into the shrouds. The outer shrouds are secured to the inner wall of the compressor case by radial retaining screws.

Some manufacturers machine a slot in the outer shrouds and run a long, thin key the length of the compressor case. The key is held in place by retaining screws to prevent the stators from turning within the case. This method is used when a one-piece compressor case is slid over the compressor and stator assembly.

Each pair of vanes in a stator acts as a diffuser. They use the divergent principle: the outlet of the vane area is larger than the inlet. This diverging area takes the high-velocity, low-pressure air from the preceding rotor stage. It converts it to a low-velocity, high-pressure airflow. Then it directs it at the proper angle to the next rotor stage. The next rotor stage will restore the air velocity that was lost because of the pressure rise. The next stator will give a further pressure rise. This process continues for each stage in the compressor.

A 1.2X-pressure rise is about as much as a single stage can handle. Higher pressure rises result in higher diffusion rates with excessive turning angles. This causes excessive air instability, hence low efficiency.

Preceding the stators and the first stage of the compressor is a row of vanes known as inlet guide vanes (IGVs). The function of the IGVs varies somewhat, depending on the size of the engine and the air-inlet construction. On smaller engines the air inlet is not totally in line with the first stage of the rotor. The IGVs straighten the airflow and direct it to the first-stage rotor. On large engines the IGVs are variable and move with the variable stators. The variable IGVs on large engines direct the airflow at the proper angle to reduce drag on the first-stage rotor. Variable IGVs achieve the same purposes as variable stator vanes (VSVs).

The variable stators are controlled by compressor inlet temperature (CIT) and engine power requirements. They are moved by mechanical linkages that are connected to the fuel-control governor. Variable stators have a twofold purpose: (1) they are positioned at various angles depending on compressor speed. They ensure the proper angle of attack between the compressor blades. Varying the blade angle helps to maintain maximum compressor efficiency over the

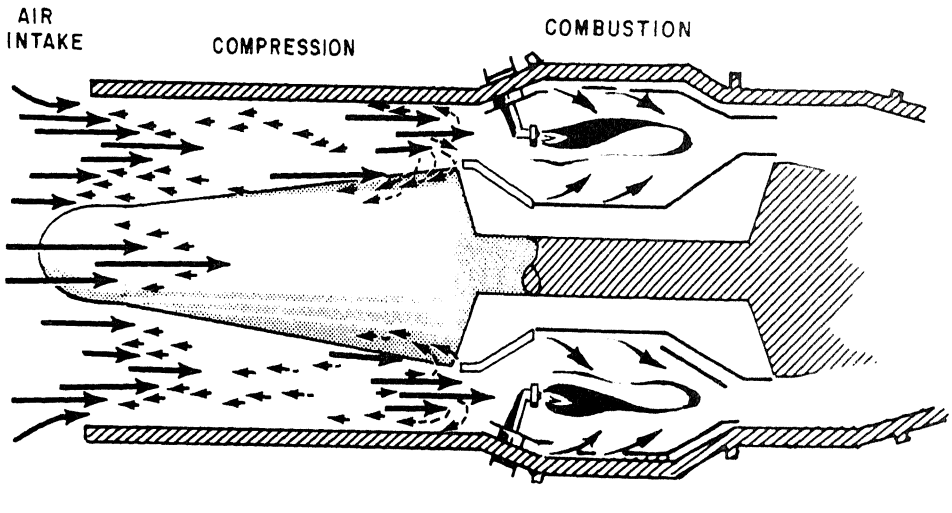


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Figure 4-20.—Compressor surge.

operating speed range of the engine. This is important in variable speed engines such as those used for main propulsion; (2) the variable stators on large engines virtually eliminate compressor surge. Surge (figure 4-20) results when the airflow stalls across the compressor blades; that is, air is not smoothly compressed into the combustion and turbine section. Stalling may occur over a few blades or a section of some stages. If enough flow is interrupted, pressure may surge back through the compressor. This occurrence can be minor or very severe with possible damage to the turbine resulting.

All the air in the combustor then may be used for combustion instead of only the primary air. Lack of cooling air may cause extreme temperatures which burn the combustor and turbine section. (By a change in the angle of the stators and the use of bleed valves, the airflow through the compressor is ensured. Compressor surge can be almost totally prevented.)

Constant-speed engines, such as those used to drive generators, normally do not use variable stators. They are designed to operate at 100-percent rpm all the time. The proper fuel schedule and bleed air valves are adequate to prevent or minimize compressor surge.

CLASSIFYING GAS TURBINES BY COMBUSTION CHAMBER DESIGN

There are three types of combustion chambers: (1) can type, (2) annular type, and (3) can-annular type. The can-type chamber is used primarily on engines that have a centrifugal compressor. The annular and can-annular types are used on axial flow compressors.

Can-Type Chamber

The can-type combustion system consists of individual liners and cases mounted around the axis of the engine. Each chamber (figure 4-21)

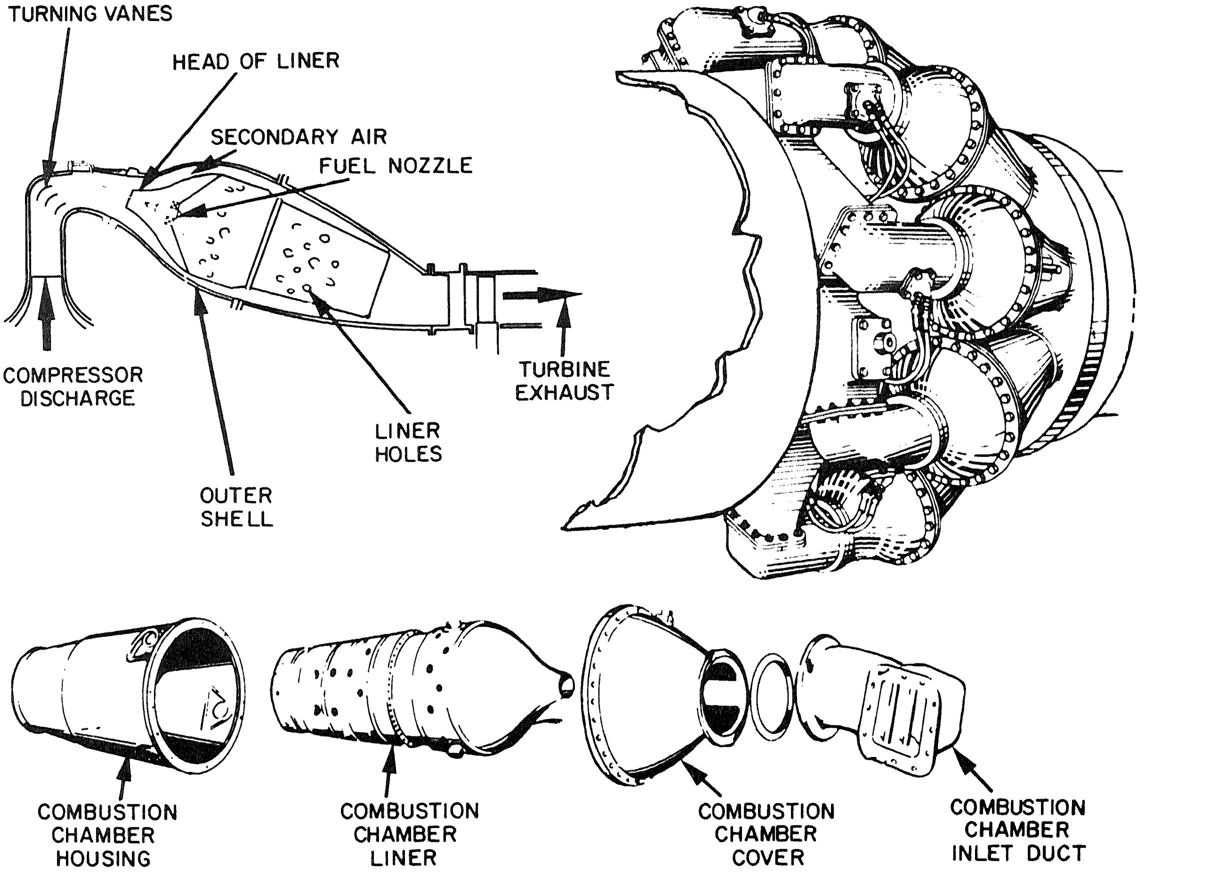

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Figure 4-21.—Elements of a can-type combustion chamber.

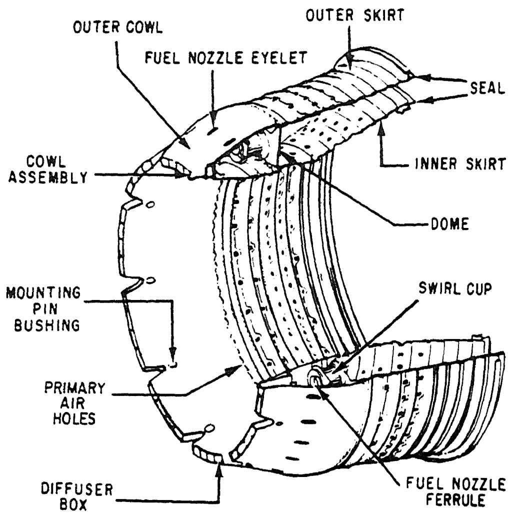
contains a fuel nozzle. This arrangement makes removing a chamber easy; however, it is a bulky arrangement and makes for a structurally weak engine. The outer casing is welded to a ring that directs the gases into the turbine nozzle. Each of the casings is linked to the others with a short tube. This arrangement ensures that combustion occurs in all the burners during engine start. Inside each of these tubes is a flame tube that joins an adjacent inner liner.

Annular-Type Chamber

The annular-type combustion chamber is usually found on axial flow engines. It is probably one of the most popular combustion systems in use. The construction consists of a housing and liner the same as the can type (figure 4-22).

The great difference is in the liner. On large engines, the liner consists of an undivided circular shroud extending all the way around the outside of the turbine shaft housing. A large one-piece combustor case covers the liner and is attached at the turbine section and diffuser section.

The dome of the liner has small slots and holes to admit primary air. They also impart a swirling motion for better atomization of fuel. There are also holes in the dome for the fuel nozzles to extend through into the combustion area. In the case of the double-annular chamber, two rows of fuel nozzles are required. The inner and outer liners form the combustion space. The outer liner keeps flame from contacting the combustor case. The inner liner prevents flame from contacting the turbine shaft housing.



277.19
Figure 4-22.—Annular-type combustion chamber.

Large holes and slots are located along the liners. They (1) admit some cooling air into the combustion space to help cool the hot gases to a safe level, (2) center the flame, and (3) admit the balance of air for combustion. The gases are cooled enough to prevent warpage of the liners.

The annular-type combustion chamber is a very efficient system that minimizes bulk. It can be used most effectively in limited space. There are some disadvantages, however. On some engines, the liners are one piece and cannot be removed without engine disassembly. Also, engines that use a one-piece combustor dome must be disassembled to remove the dome.

Can-Annular Type of Chamber

The can-annular type of combustion chamber combines some of the features of both the can and the annular burners.

The can-annular type of chamber design is a result of the split spool compressor concept. Problems were encountered with a long shaft and with one shaft within the other. Because of these problems a chamber was designed to perform all the necessary functions.

In the can-annular type of chamber individual cans are placed inside an annular case. The cans are essentially individual combustion chambers (figure 4-23) with concentric rings of perforated holes to admit air for cooling. On some models each can has a round perforated tube which runs down the middle of the can. The tube carries additional air which enters the can through the perforations to provide more air for combustion and cooling. The effect is to permit more burning per inch of can length than could otherwise be done.

Fuel nozzle arrangement varies from one nozzle in each can to several nozzles around the perimeter of each can.

The cans have an inherent resistance to buckling because of their small diameter. Each can has two holes which are opposite each other near the forward end of the can. One hole has

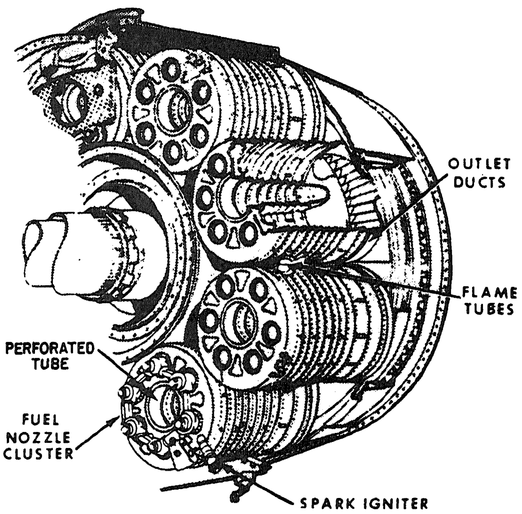


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Figure 4-23.—Can-annular type combustion chamber, components and arrangement.

a collar called a flame tube. When the cans are assembled in the annular case, these holes and their collars form open tubes. The tubes are between adjacent cans so that a flame passes from one can to the next during engine starting.

The short length of the can-annular type of chamber is a structural advantage. It provides minimal pressure drop of the gases between the compressor outlet and the flame area. Another advantage of the can-annular engine is the greater structural strength it gets from its short combustor area. Maintenance is also simple. You can just slide the case back and remove any one burner for inspection or repair. Another good feature is the relatively cool air in the annular outer can. It tends to reduce the high temperatures of the inner cans. At the same time, this air blanket keeps the outer shell of the combustion section cooler.

CLASSIFICATION OF GAS TURBINES BY TYPE OF SHAFTING

Several types of gas turbine shafts are used. These are SINGLE SHAFT, SPLIT SHAFT, and TWIN SPOOL. Of these, the single shaft and split shaft are the most common in use in naval vessels. We will mention the twin spool type and give a brief description. The USCG *Hamilton* class cutters use the Pratt-Whitney FT-4 twin spool gas turbine.

In current U.S. Navy service the single shaft engine is used primarily for driving ship's service generators. The split shaft engine is used for main propulsion as a variety of speed ranges is encountered.

Figure 4-24 is a block diagram of a single shaft gas turbine. In the engine illustrated, the power

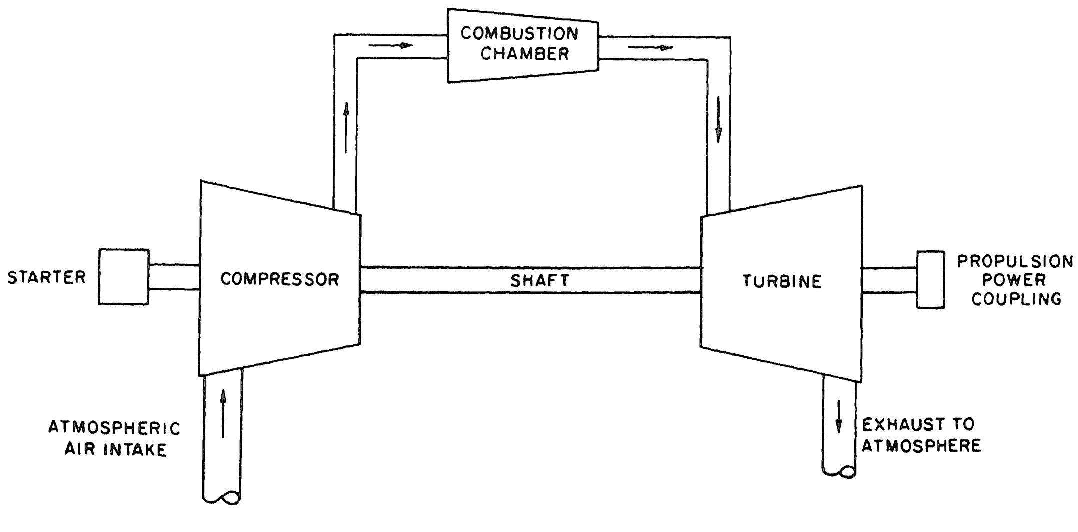

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Figure 4-24.—Single shaft engine.

output shaft is connected directly to the same turbine rotor that drives the compressor. In most cases, there is a speed decreaser or reduction gear between the rotor and the power output shaft; however, there is still a mechanical connection throughout the entire engine.

In the split shaft engine (figure 4-25), there is no mechanical connection between the GG turbine and the PT. With this type of engine the

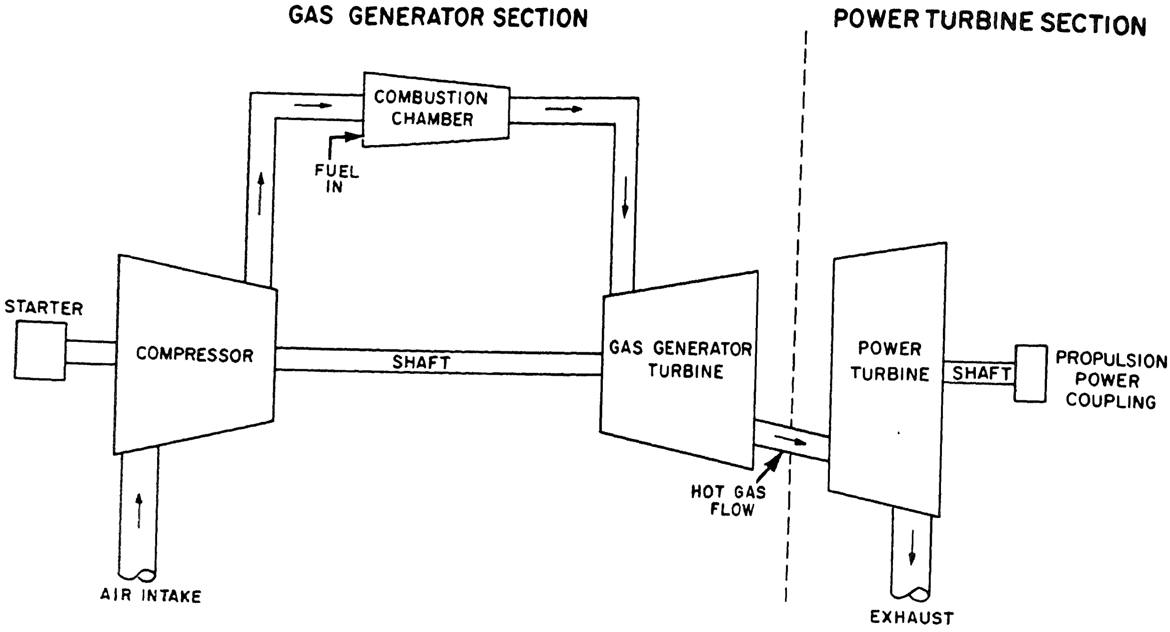

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Figure 4-25.—Split shaft engine.

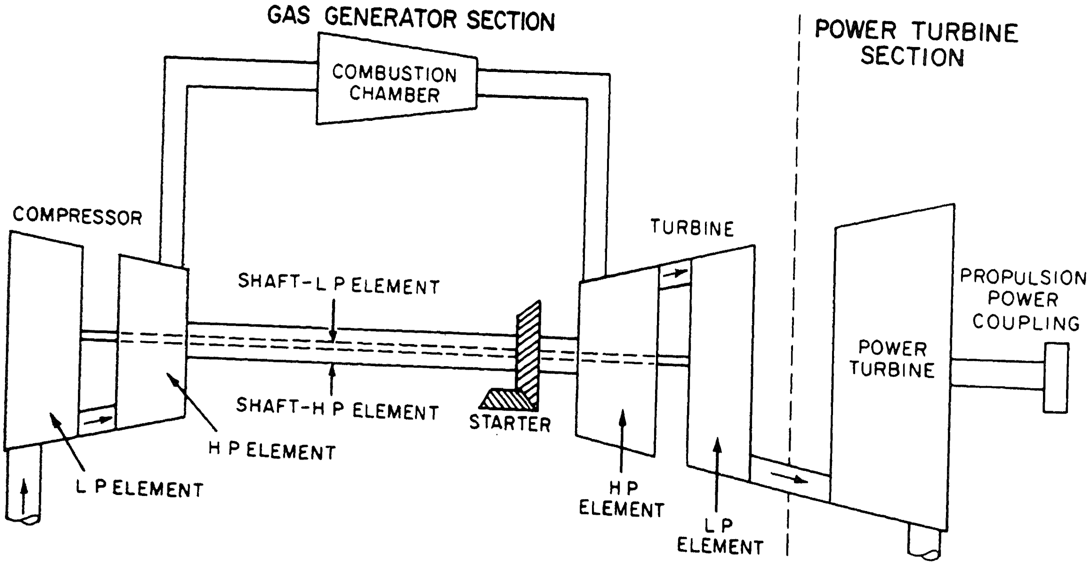

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Figure 4-26.—Twin spool engine.

output speed can be varied by varying the generator speed. Also, under certain conditions, the GG can run at a reduced rpm and still provide maximum PT rpm. The reduced rpm greatly improves fuel economy and also extends the life of the GG turbine. The starting torque required is lowered. This is because the PT, reduction gears, and output shaft are stationary until the GG reaches approximate idle speed. Another feature is that in a multishaft marine propulsion plant the GG rotates only one way. One design (clockwise rotation or counterclockwise rotation) of the GG can be used on either shaft; however, the PT can be made to rotate either way. This is done by changing the PT wheel and nozzles. The arrangement shown in figure 4-25 is typical for propulsion gas turbines aboard the DD-963 and FFG-7 class ships.

Another type of turbine is the twin spool, sometimes referred to as a multistage gas turbine. In the twin spool engine there are two separate compressors and two separate turbine rotors. They are referred to as low-pressure (LP) compressor and turbine rotor and high-pressure (HP) compressor and turbine rotor (figure 4-26). The LP compressor and turbine are connected by a shaft. The shaft runs through the hollow shaft that connects the HP turbine to the HP compressor. The starter drives the HP assembly during engine start. The PT functions the same as in the split shaft engine. A larger volume of air can be handled as compared to a single or split shaft engine; however, the engine has more moving parts. The increase in overall dimensions and complexity makes the engine less desirable for ship's propulsion than the split shaft engine.

TURBINE ASSEMBLIES

Gas turbine engines are not normally classified by turbine type. We will discuss turbines now so you will understand their construction before covering specific engines in the next chapters.

In theory, design, and operating characteristics, the turbines used in GTEs are similar to those used in a steam plant. The gas turbine differs from the steam turbine chiefly in (1) the type of blading material used, (2) the means provided for cooling the turbine shaft bearings, and (3) the lower ratio of blade length to wheel diameter.

The terms GG turbine and PT are used to differentiate between the turbines. The GG turbine powers the GG and accessories. The PT powers the ship's propeller through the reduction gear and shafting.

The turbine that drives the compressor of a GTE is located directly behind the combustion chamber outlet. The turbine consists of two basic elements, the stator or nozzle, and the rotor. Part of a stator element is shown in figure 4-27; a rotor element is shown in figure 4-28.

Turbine Stators

The stator element of the turbine section is known by a variety of names. The three most

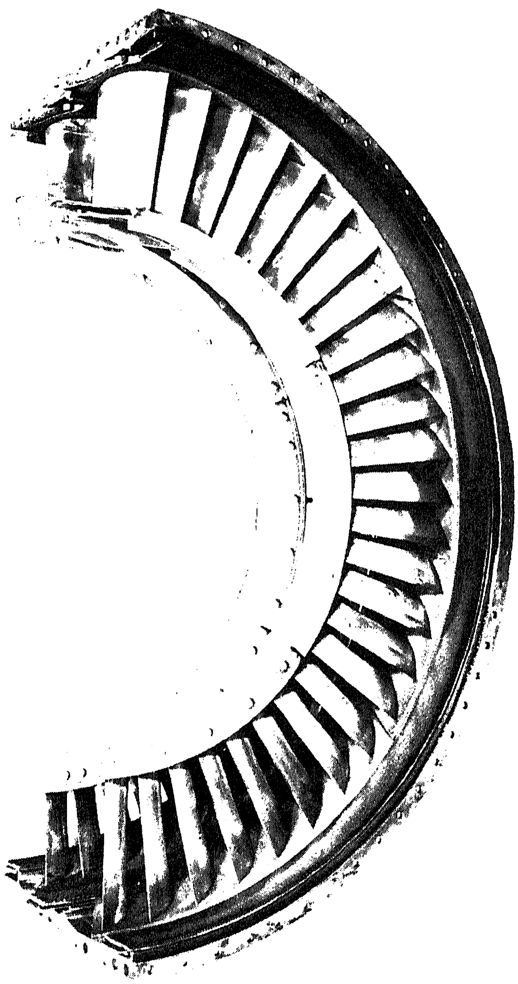

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Figure 4-27.—Cutaway of a turbine stator.

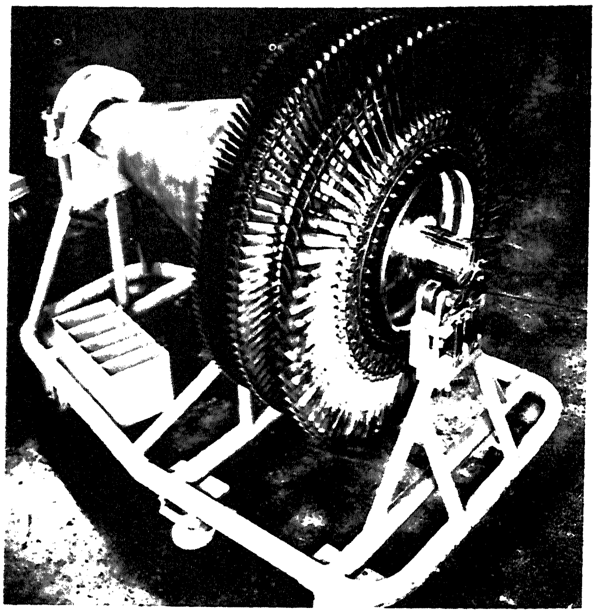

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Figure 4-28.—Turbine rotor elements.

common are turbine nozzle vanes, turbine guide vanes, and nozzle diaphragm. In this text, turbine stators are usually referred to as nozzles. The turbine nozzle vanes are located directly aft of the combustion chambers and immediately forward of, and between the turbine wheels.

Turbine nozzles have a twofold function. First, the nozzles prepare the mass flow for harnessing of power through the turbine rotor. This occurs after the combustion chamber has introduced the heat energy into the mass airflow and delivered it evenly to the nozzles. The stationary vanes of the turbine nozzles are contoured and set at a certain angle. They form a number of small nozzles that discharge the gas as extremely high-speed jets; thus, the nozzle converts a varying portion of the heat and pressure energy to velocity energy. The velocity energy can then be converted to mechanical energy through the rotor blades.

The turbine nozzle functions to deflect the gases to a specific angle in the direction of turbine wheel rotation. The gas flow from the nozzle must enter the turbine blade passageway while it is still rotating. Therefore, it is essential to aim the gas in the general direction of turbine rotation.

The turbine nozzle assembly consists of an inner shroud and an outer shroud between which are fixed the nozzle vanes. The number of vanes varies with different types and sizes of engines. Figure 4-29 illustrates typical turbine nozzles featuring loose and welded vane fits.

The vanes of the turbine nozzle are assembled between the outer and inner shrouds or rings in different ways. Although turbine nozzles may differ in their construction, there is one characteristic special to all turbine nozzles; that is, the nozzle vanes must be constructed to allow for thermal expansion. Otherwise, rapid temperature variances could cause distortion or warping of the metal components.

Thermal expansion of turbine nozzles is accomplished by one of several methods. In one method the vanes are assembled loosely in the supporting inner and outer shrouds (figure 4-29, item A). Each of the vanes fits into a contoured slot in the shrouds. The slots conform with the airfoil shape of the vanes. These slots are slightly larger than the vane to give a loose fit. For further support the inner and outer shrouds are encased by an inner and an outer support ring.

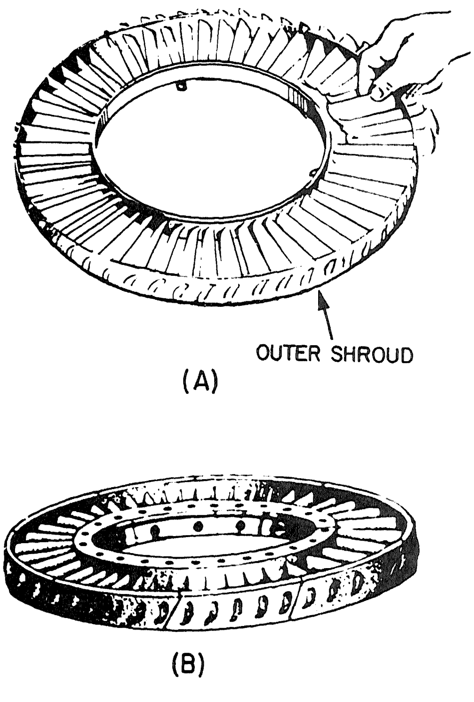

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Figure 4-29.—(A) Turbine nozzle vane assembly with loose-fitting vanes; (B) turbine nozzle vane assembly with welded vanes.

This adds strength and rigidity to the turbine nozzle. These supports also permit removal of the nozzle vanes as a unit; otherwise, the vanes could fall out of the shrouds as the shrouds are removed.

Another method to allow for thermal expansion is to fit the vanes into inner and outer shrouds. In this method the vanes are welded or riveted into position (figure 4-29, item B). Either the inner or the outer shroud ring is cut into segments to provide for thermal expansion. The saw cuts dividing the segments will allow enough expansion to prevent stress and warping of the vanes.

The basic types of construction of nozzles are the same for all types of turbines. The convergent-divergent principle (Bernoulli's principle) is used to increase gas velocity.

The turbine nozzles are made of high-strength steel. Steel can withstand the direct impact of the hot, high-pressure, high-velocity gases from the combustor. The nozzle vanes must also resist erosion from the high-velocity gases passing over them.

Increasing the inlet gas temperature by about 750 °F achieves almost a 100-percent increase in specific horsepower. However, nozzles do not stand up for long to the higher temperatures. Different methods of increasing nozzle endurance have been tried over the years.

One method that was tried was to coat the nozzle with a ceramic coating. Higher temperatures were achieved. However, the different expansion rates of the steel and the ceramic caused the coating to break away over a period of time. Experiments are still being conducted, even so far as to use an entirely ceramic nozzle.

Another means of withstanding high temperatures is to use newly developed alloys. However, extreme costs of the alloys prohibit commercial production of such nozzles.

Still another method, which is in wide use today in large engines, is to use air-cooled nozzle vanes. Compressor bleed air is fed through passages to the turbine where it is directed to the nozzle. The air cools both the turbine (discussed later) and the nozzle. The nozzle may also be cooled by air admitted from the outer perimeter of the nozzle ring. The method of getting the air in is determined by the manufacturer.

The nozzle vanes are made with many small holes or slots on the leading and trailing edges (figure 4-30). Air is forced into the nozzle and

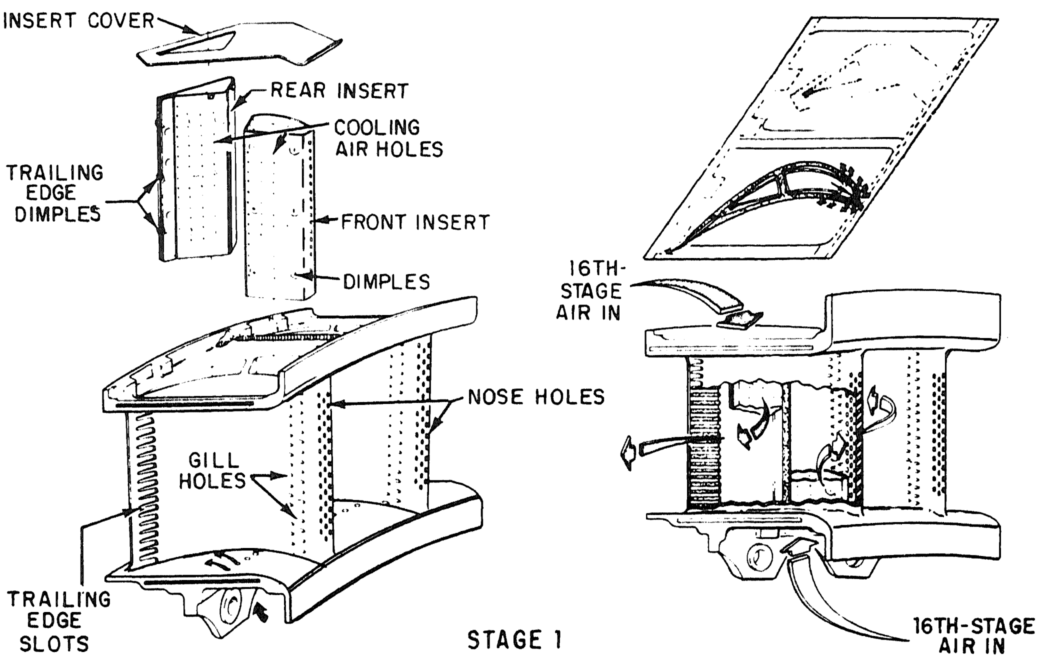

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Figure 4-30.—First-stage gas generator turbine nozzle cooling.

out through the slots and holes. The vane is cooled as the air passes through. The air is discharged into the hot gas stream, passing through the remainder of the turbine section. Then it passes out the exhaust duct.

Figure 4-31 compares temperature of an air-cooled vane against a nonair-cooled vane.

Cooling air is used primarily in the HP turbine section. The temperature of the gases is at an acceptable level by the time the gases reach the LP turbine section. In this section metals in current usage will last for long periods of time.

Seals installed between the nozzle entrance shroud and the turbine shaft may be pressurized with bleed air. This helps to minimize interstage leakage of the gases as they pass through the turbine.

Turbine Rotors

The rotor element of the turbine consists of a shaft and bladed wheel(s). The wheel(s) are attached to the main power transmitting shaft of the GTE. The jets of combustion gas leaving the vanes of the stator element act upon the turbine blades. Thus the turbine wheel can rotate in a speed range of about 3600 to 42,000 rpm. The high rotational speed imposes severe centrifugal loads on the turbine wheel. At the same time the high temperature (1050° to 2300°F) results in a lowering of the strength of the material.

Consequently, the engine speed and temperature must be controlled to keep turbine operation within safe limits. The operating life of the turbine blading usually determines the life of the GTE.

The turbine wheel is a dynamically balanced unit consisting of blades attached to a rotating disk. The disk in turn is attached to the rotor shaft of the engine. The high-velocity exhaust gases leaving the turbine nozzle vanes act on the blades of the turbine wheel. This causes the assembly to rotate at a very high rate of speed.

The turbine disk is referred to as such when in an unbladed form. When the turbine blades are installed, the disk then becomes the turbine wheel. The disk acts as an anchoring component for the turbine blades. The disk is bolted or welded to the shaft. This enables the blades to transmit to the rotor shaft the energy they extract from the exhaust gases.

The disk rim is exposed to the hot gases passing through the blades and absorbs considerable heat from these gases. In addition, the

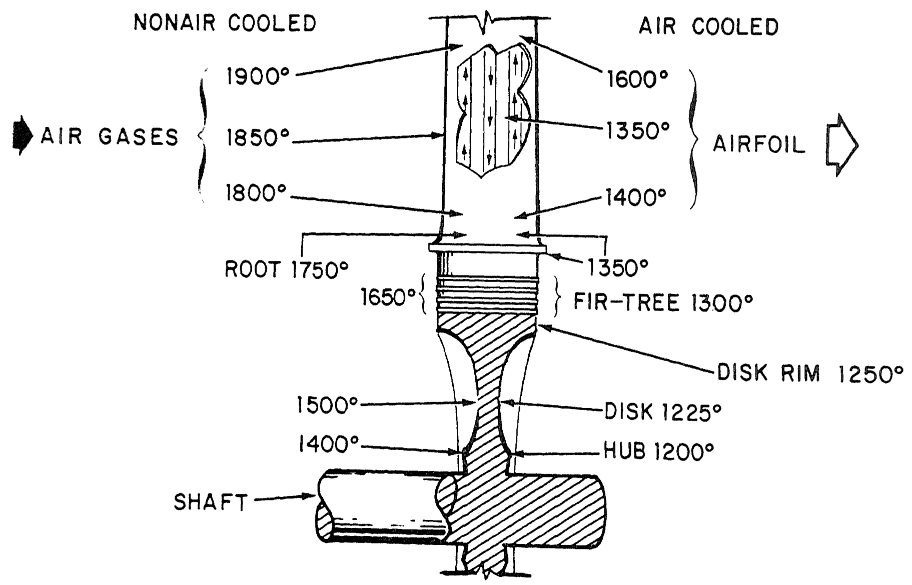

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Figure 4-31.—Cooling comparisons between an air-cooled vane and a nonair-cooled vane.

rim also absorbs heat from the turbine blades by conduction. Hence, disk rim temperatures normally are high and above the temperatures of the remote inner portion of the disk. As a result of these temperature gradients, thermal stresses are added to the stresses caused by rotation.

Various means are provided to relieve, at least partially, the stresses. One way is to incorporate an auxiliary fan somewhere ahead of the disk, usually rotor shaft-driven. This will force cooling air back into the face of the disk.

Another method of relieving the thermal stresses of the disk follows as incidental to blade installation. By notching the disk rims to conform with the blade root design, the disk is made able to retain the turbine blades. Also space is provided by the notches for thermal expansion of the disk.

The turbine shaft is usually made from low-alloy steel. It must be capable of absorbing high torque loads, such as exerted when a heavy axial flow compressor is started.

The methods of connecting the shaft to the turbine disk vary. One method used is welding. The shaft is welded to the disk, which has a butt or protrusion provided for the joint. Another method is by bolting. This method requires that the shaft have a hub which matches a machined surface on the disk face. The bolts then are inserted through holes in the shaft hub. They are anchored in tapped holes in the disk. Of the two methods, the latter is more common.

The turbine shaft must have some means for joining the compressor rotor hub; this is usually accomplished by making a splined cut on the forward end of the shaft. The spline fits into a coupling device between the compressor and the turbine shafts. If a coupling is not used, the splined end of the turbine shaft fits into a splined recess in the compressor rotor hub. The centrifugal compressor engines use the splined coupling arrangement almost exclusively. Axial compressor engines may use either of these described methods.

There are various ways of attaching turbine blades. Some ways are similar to the way compressor blades are attached. The most satisfactory method used is the fir-tree design shown in figure 4-32.

The blades are retained in their respective grooves by a variety of methods. Some of the more common methods are peening, welding, locking tabs, and riveting. Figure 4-33 shows a typical turbine wheel using riveting for blade retention.

The peening method of blade retention is often used. Its use may be applied in various ways. Two of the most common applications of peening are described in the following paragraphs.

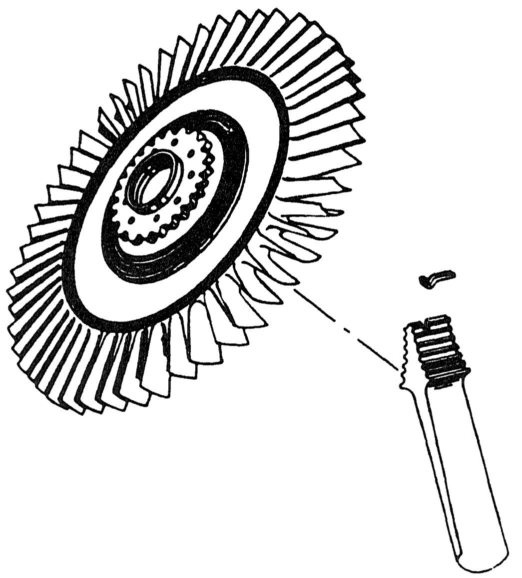

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Figure 4-32.—Turbine blade with fir-tree design and tab lock method of blade retention.

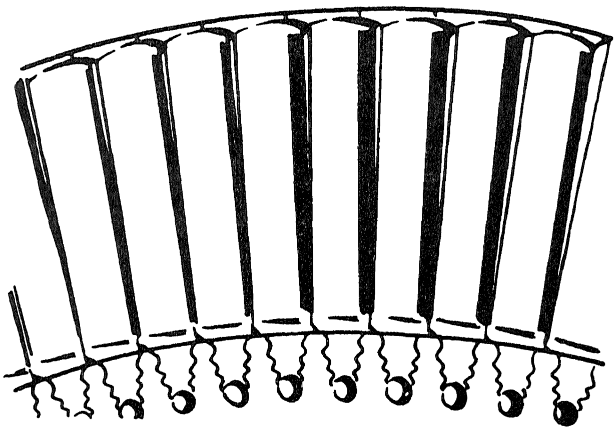

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Figure 4-33.—Riveting method of turbine blade retention.

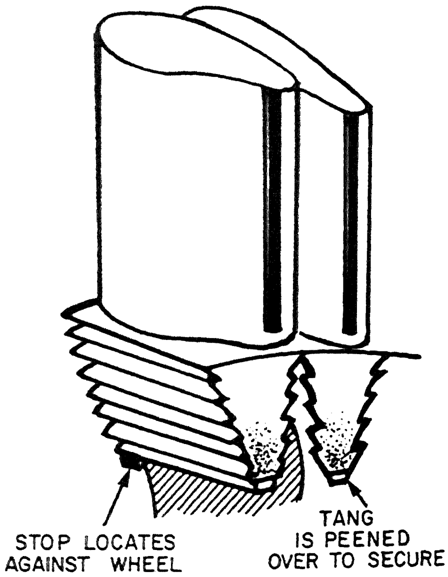

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Figure 4-34.—Turbine blade featuring peening method of blade retention.

One peening method requires you to grind a small notch in the edge of the blade fir-tree root. You do this before installing the blade. After you have installed the blade in the disk, the notch will fill with the disk metal. The disk metal is flowed into it through a small punchmark made in the disk adjacent to the notch. The tool you use for this job is similar to a centerpunch and is usually manufactured locally.

Another peening method is to construct the root of the blade so it contains the necessary retention elements. This method (figure 4-34) shows that the blade root has a stop made on one end of the root. The blade may be inserted and removed in one direction only. On the opposite end is a tang. You peen this tang over to secure the blade in the disk.

Turbine blades may be either forged or cast, depending on the metal they are made of. Turbine blades are usually machined from individual forgings. Various materials are used in the forging. Speed and operating temperatures are important factors that decide which materials go into the turbine blades.

Large engines use an air-cooled blading arrangement on the GG turbine (figure 4-35). Compressor discharge air is constantly fed through passages along the forward turbine shaft

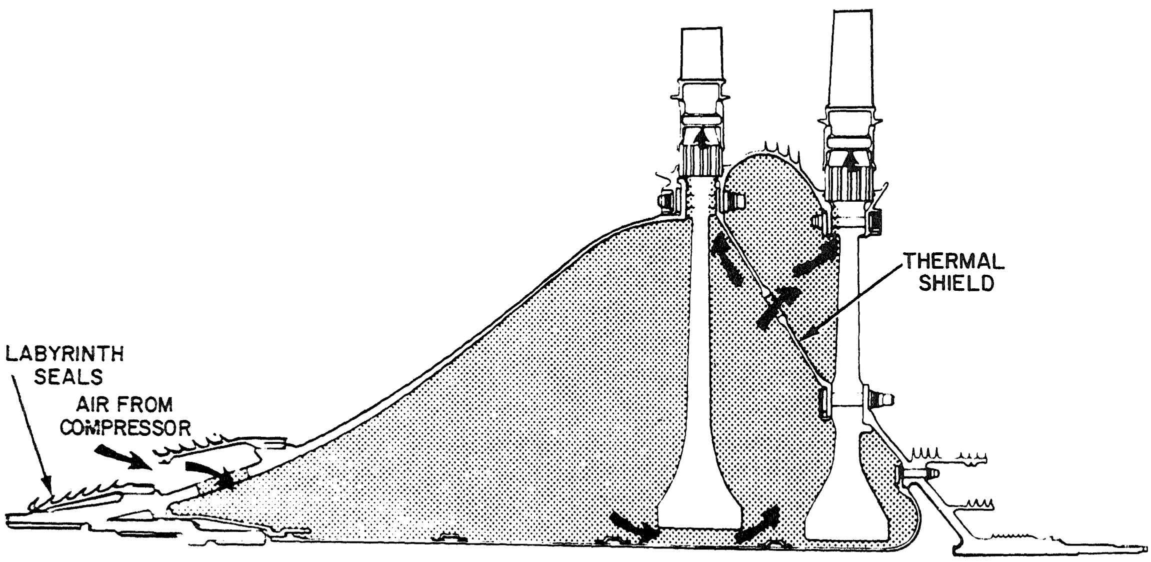

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Figure 4-35.—Gas generator turbine rotor cooling airflow.

between a spacer and the shaft. A thermal shield directs the cooling air along the face of the disk for cooling of the disk. The shield is between the first- and second-stage turbine wheels. The air is then directed through slots in the fir-tree portion of the disk, into slots in the blade fir-tree. The air then goes up through holes in the blades to cool the blades (figure 4-36).

Cooling of the turbine wheel and blades reduces thermal stresses on the rotating members. The turbine nozzles are also air cooled. By cooling the stationary and rotating parts of the turbine section, higher turbine inlet

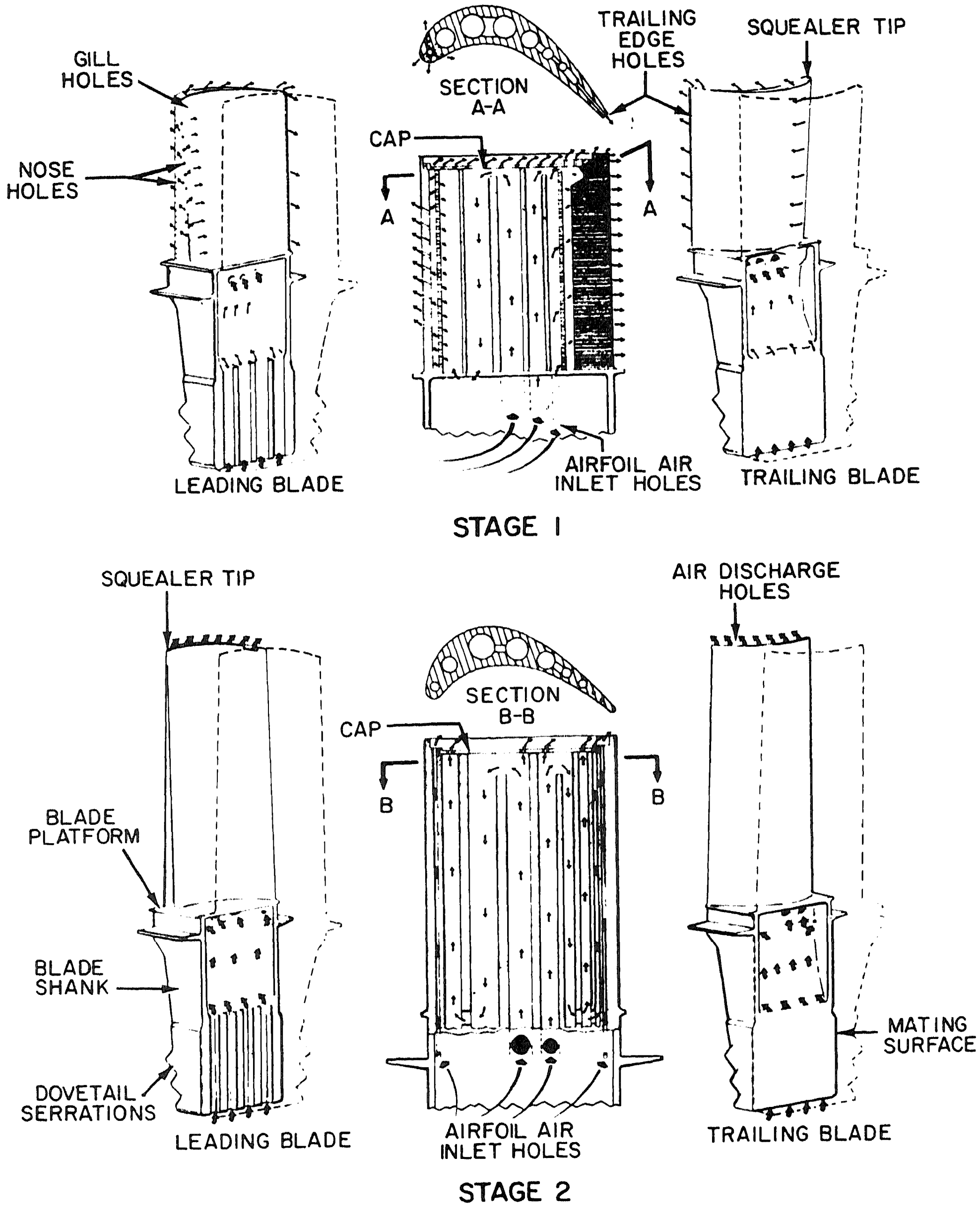

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Figure 4-36.—Gas generator turbine rotor blade cooling.

temperatures are permissible. The higher temperatures allow for more power, a more efficient engine, and longer engine life.

POWER TURBINES

Power turbines are used to extract the remaining energy from the hot gas. Power turbine wheels are used three different ways.

1. The aircraft jet turbine is designed so the turbine extracts only enough energy from the gases to run the compressor and accessories.
2. In the solid-wheel turbine, as much energy as possible is extracted from the gases to turn the turbine. The turbine provides power for the

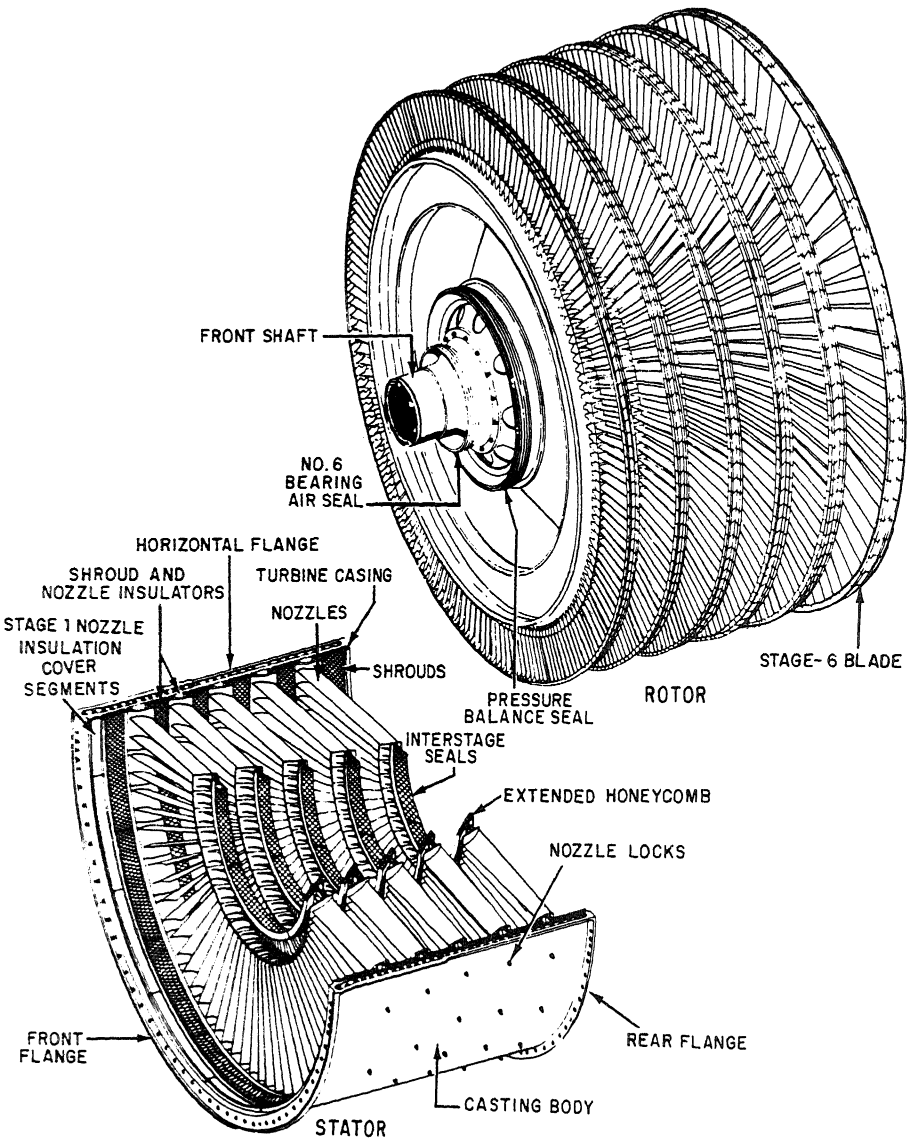

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Figure 4-37.—Typical power turbine.

compressor, accessories, and the airplane propeller or the ship's generator. Examples of these engines are a turboprop airplane or ship's service generator engine. These engines are designed to run at 100 percent specified rpm all the time. The location of the mechanical connection between the turbine wheel and the reduction gear on the compressor front shaft depends on the design of the installation. Normally, a ship's service generator cannot be disconnected from its gas turbine except by disassembly. This setup is used for generators to prevent slippage between the engine and the generator.

3. Marine propulsion engines use a combination of the two engine types. The GG has a single or dual stage high-pressure rotor that drives the compressor and accessories.

The PT (figure 4-37) is a multistage turbine located behind the GG turbine. There is no mechanical connection between the two turbines. The PT is connected to a reduction gear through a clutch mechanism. Either a controllable reversible pitch propeller or a reverse gear is used to change direction of the vessel.

Some ships that have two sets of engines use counterrotating PTs. For example, PTs on one shaft rotate clockwise while the turbines on the other rotate counterclockwise. This arrangement eliminates the use of a V-drive. The GG portion rotates in the same direction for both sets of engines. The blade angle of the wheel and the nozzles in the PT section determine the directional rotation of the PT. On large ships where different length propeller shafts are permitted, the engine(s) can be mounted to the other end of the reduction gear. In this way counterrotation of the propellers is achieved.

By varying the GG speed, the output speed of the PT can be controlled. Since only a portion of the energy is used to drive the compressor, the plant can be operated very efficiently. For example, on a cold day you can have 100 percent power turbine rpm with 80 to 90 percent gas generator rpm. The variables discussed earlier in the chapter account for this situation.

The PT is constructed much like the GG turbine. The main differences are (1) the absence of cooling air and (2) the PT blades have interlocking shroud tips for low vibration levels. Honeycomb shrouds in the turbine case mate with the blade shrouds to provide a gas seal. They also protect the case from the high-temperature gas. Two popular methods of blade retention are the bulb type and the dovetail. These methods were discussed earlier in this chapter.

SUMMARY

In this chapter you have learned about principles and construction of GTEs. We have discussed the evolution of the gas turbine, the theory of operation, and the classifications of the different types of engines. There are many other publications that give a more in-depth explanation of gas turbine construction. This chapter was provided to give you the basis on which to expand your knowledge of naval gas turbine engines. You may not feel you understand the temperature-pressure relationships in a simple gas turbine at this point. If so, reread the parts of this chapter related to theory before continuing on to the material that follows.

REFERENCE

Introduction to Marine Gas Turbines, NAVEDTRA 10094. Naval Education and Training Program Development Center, Pensacola, Fla., 1978.

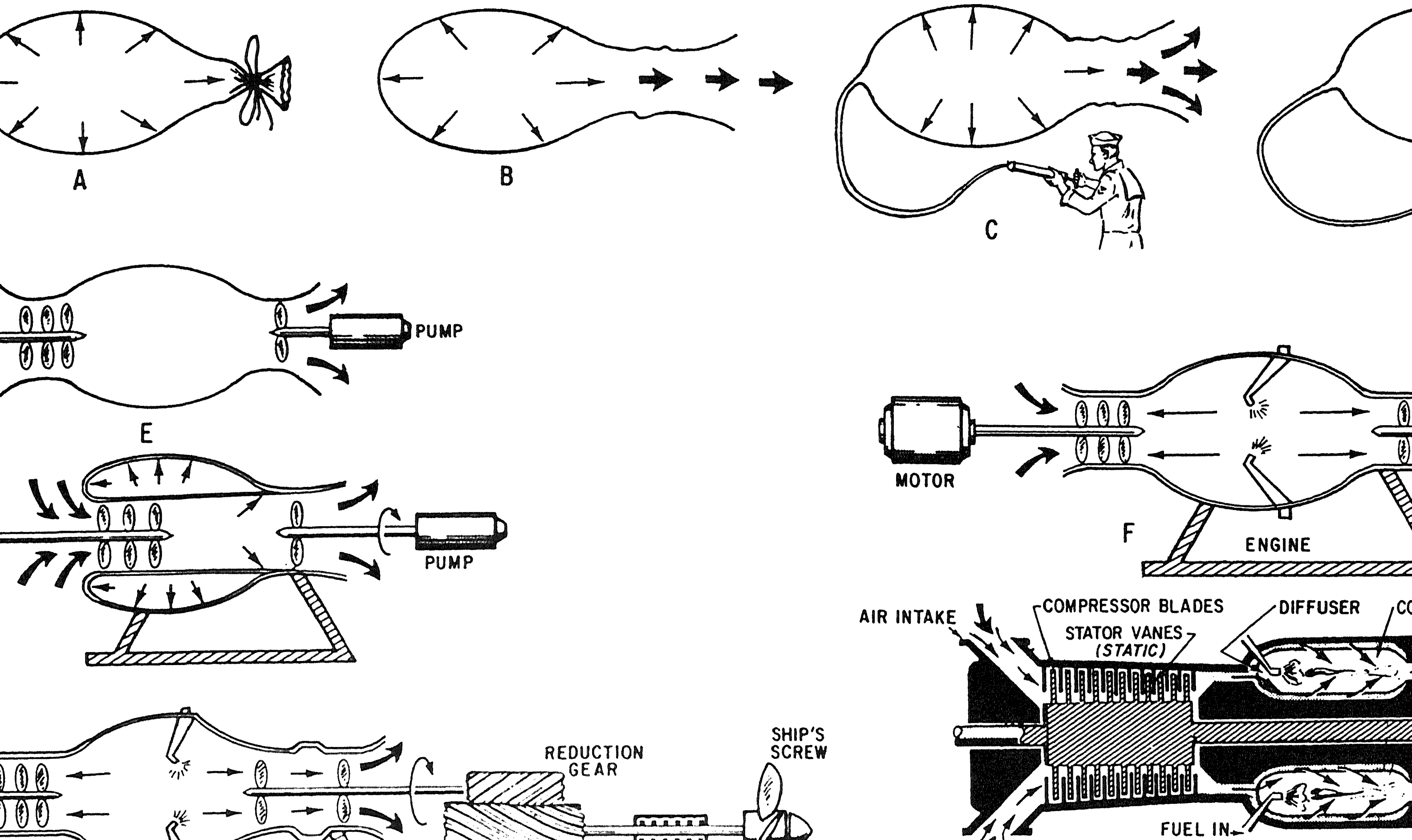

Figure 4-10.—Practical demonstration of gas turbin

CHAPTER 5

LM2500 GAS TURBINE CONSTRUCTION

An important part of a GSE's job is to monitor the performance of the LM2500 gas turbine (GT). GSEs make any necessary adjustments to improve or correct the performance of the LM2500 in the FSEE. In discussing the LM2500, we will break down the engine into components and systems. The components we will discuss are the FOD screen and bellmouth, the compressor, combustor, high-pressure (HP) and power turbines, and the accessory gearbox. The systems covered include the fuel oil, lube oil, air intake exhaust, module cooling, and starting systems. We will also cover the base enclosure.

After reading this chapter, you should be very familiar with the construction of the LM2500 GT. You should be able to describe the engine components and their functions. Also, you should be able to discuss the engine systems and how they perform to achieve engine operations.

LM2500 ENGINE COMPONENTS

The LM2500 (figure 5-1) is an axial flow, split shaft gas turbine with an annular-type combustion chamber. The GG components consist of an FOD screen, a bellmouth, and a 16-stage variable geometry compressor. The GG components also include an annular-type combustion chamber and a two-stage HP turbine. The accessory gearbox is mounted on the GG. The PT is aerodynamically linked to the GG and is a six-stage LP turbine. This section will describe each of these components and its function in the engine.

FOD SCREEN

The FOD screen, or air inlet screen (figure 5-2), is mounted on the module barrier wall. The purpose of this screen is to prevent foreign objects larger than 1/4 inch from entering the engine. Normally, the demister pads located in the high hat prevent particles much smaller than this from entering the air intake. The main purpose of the FOD screens is to catch anything that was inadvertently left in the inlet duct. This could include metal particles, tools, or cleaning equipment; although all these items should be removed before engine start. The screen will also prevent items from entering the engine should the blow-in doors open.

After major work, major intake cleaning, or anytime the ship is coming out of a shipyard environment, a special screen is used. It is a nylon screen that attaches over the metal FOD screen.

The nylon screen will catch particles much smaller than the metal screen. You must be careful not to exceed specified throttle limitations when using the nylon screen. Exceeding throttle limitations could starve the engine for air and cause a compressor stall. NAVSEA issues specific instructions for use of the nylon FOD screen.

BELLMOUTH AND BULLETNOSE

The bellmouth and bulletnose (centerbody) (figure 5-2) are mounted on the forward end of the compressor front frame. These components are used to direct air from the inlet plenum to the compressor. The surfaces of the two components are coated to make them smooth to reduce the turbulence of the airflow into the engine. The bellmouth also contains the water wash manifold. The water wash manifold is used to inject fresh water and/or a cleaning solution into the engine. This is done when the engine is being motored.

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Figure 5-1.—LM2500 gas turbine engine.

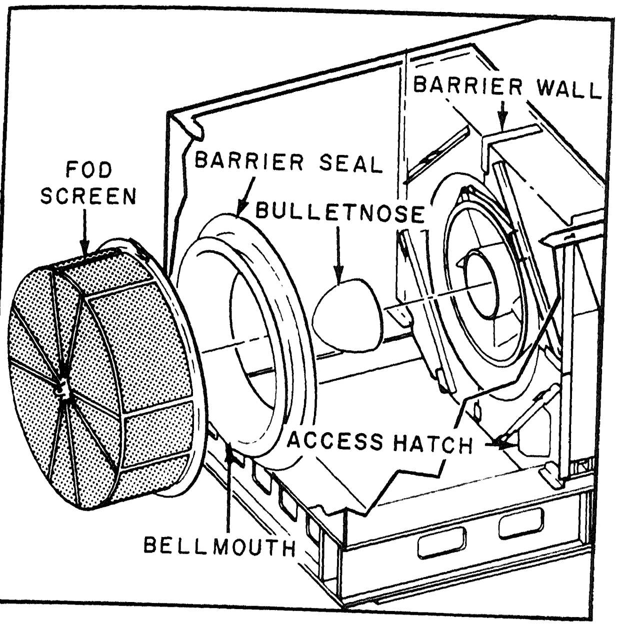

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Figure 5-2.—LM2500 inlet (FOD screen, bulletnose, and bellmouth).

This procedure is for maintenance purposes to clean deposits from the compressor. The water wash manifold is supplied by a common water wash system piped as a ship's system. We will discuss water wash procedures in chapter 6.

COMPRESSOR

The LM2500 compressor (figure 5-3) is a 16-stage, HP ratio, axial flow design. Major components are the compressor front frame, compressor stator, compressor rotor, and compressor rear frame. The primary purpose of the compressor section is to compress air for combustion; however, some of the air is extracted for engine cooling, sump seal pressurization, and bleed air for ship's service use. Air is drawn in through the front frame. Then it passes through successive stages of compressor rotor blades and compressor stator vanes. The air is compressed as it passes

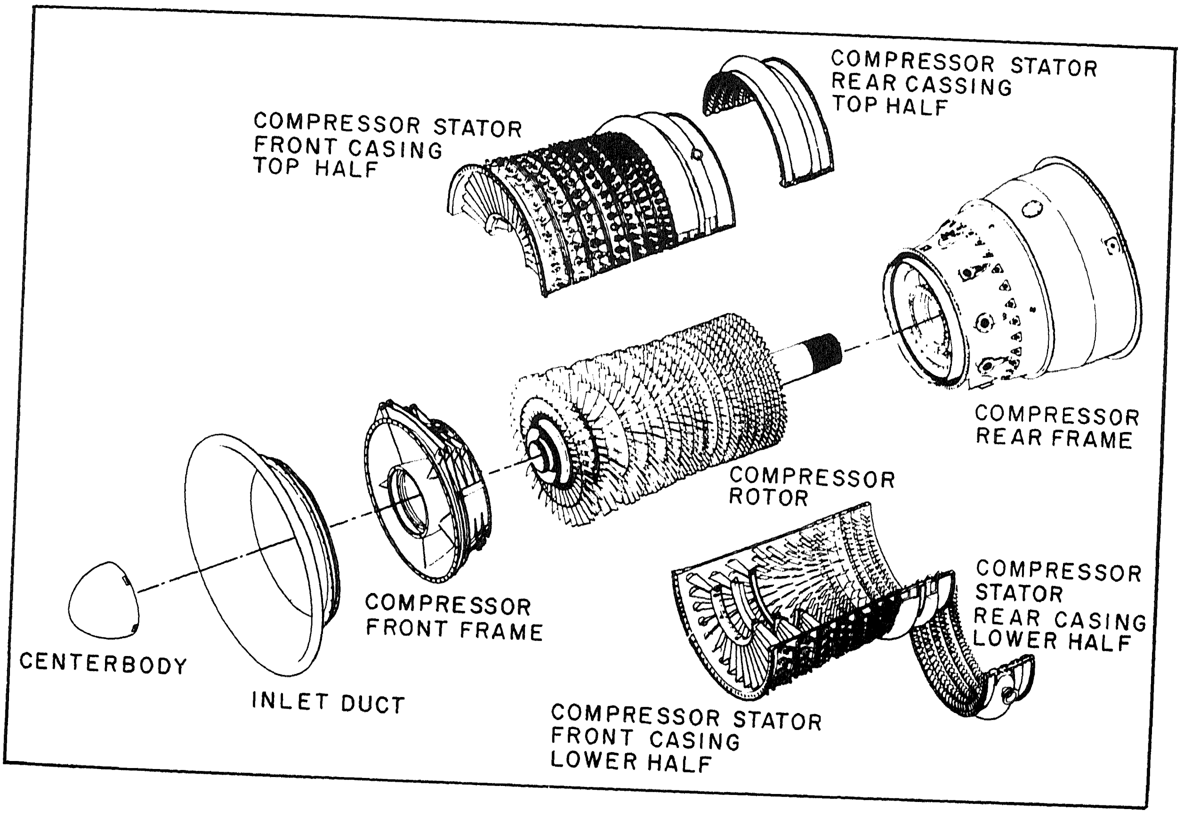

Figure 5-3.—LM2500 compressor components.

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from stage to stage. After passing through 16 stages, the air has been compressed in the ratio of about 16 to 1. The IGVs and first six stages of stator vanes are variable; their angular position is varied as a function of GG speed and CIT by hydraulic fuel pressure from the main fuel control. This provides stall-free operation of the compressor throughout a wide range of speed and inlet temperature. Because these blades are able to be set at different angles, the term variable geometry applies to this compressor.

Compressor Front Frame

The compressor front frame (figure 5-4) provides the forward attachment point for the gas turbine. It supports the forward end of the compressor section and forms a flow path for compressor inlet air. Five struts between the hub

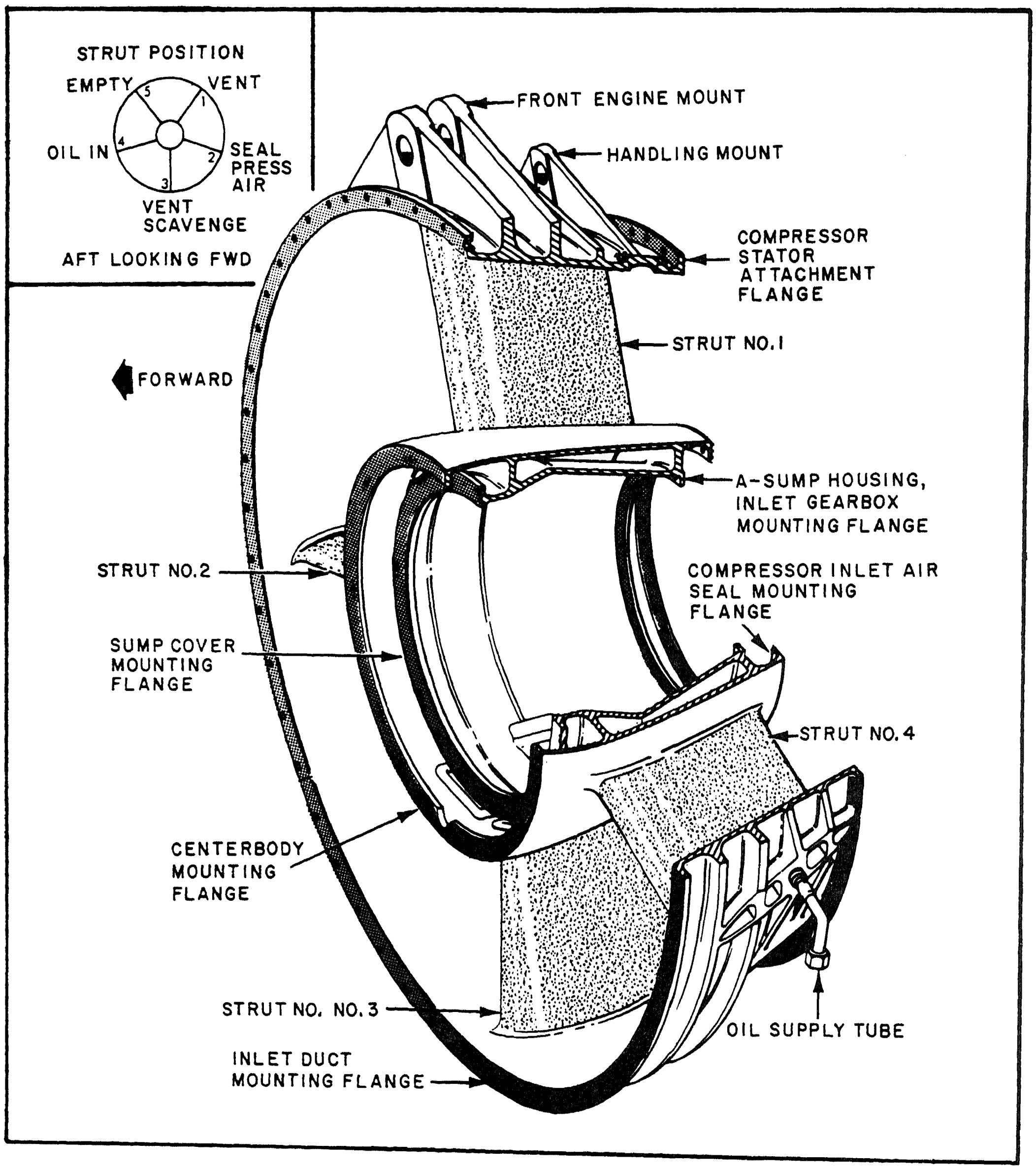

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Figure 5-4.—Propulsion gas turbine module LM2500.

and the outer case provide passages for lubrication oil, scavenge oil, and seal pressurization air. They also vent the A sump components. The No. 3 bearing supports the forward end of the compressor rotor. It and the inlet gearbox are located in the A sump. The compressor inlet total pressure (P_{t2}) probe and CIT sensor are mounted in the outer case. The No. 3 strut (6 o'clock circumferential location) houses the radial drive shaft. The radial drive shaft transfers power from the inlet gearbox to the transfer gearbox mounted on the bottom of the frame.

Compressor Stator

The compressor stator (figure 5-5) has 1 stage of IGVs and 16 stages of stator vanes. The IGVs and stages one through six are variable. The stator case consists of four sections bolted together. These sections are the upper and lower front half and the upper and lower rear half. Three bleed manifolds are welded to the stator casings. The air used for sump seal pressurization and cooling is eighth-stage air. It is extracted from inside the annulus area at the tips of the hollow

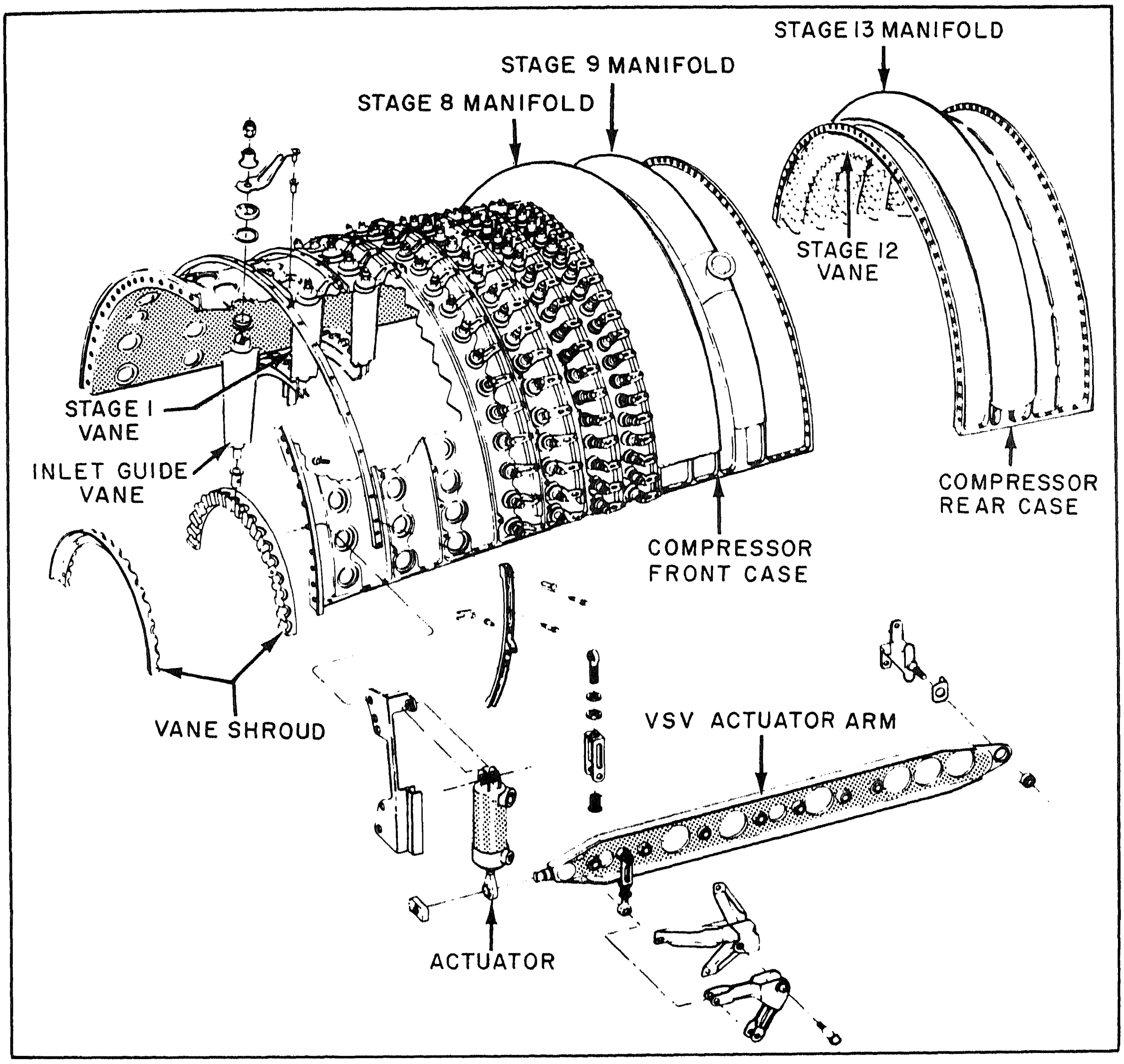

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Figure 5-5.—Compressor stator.

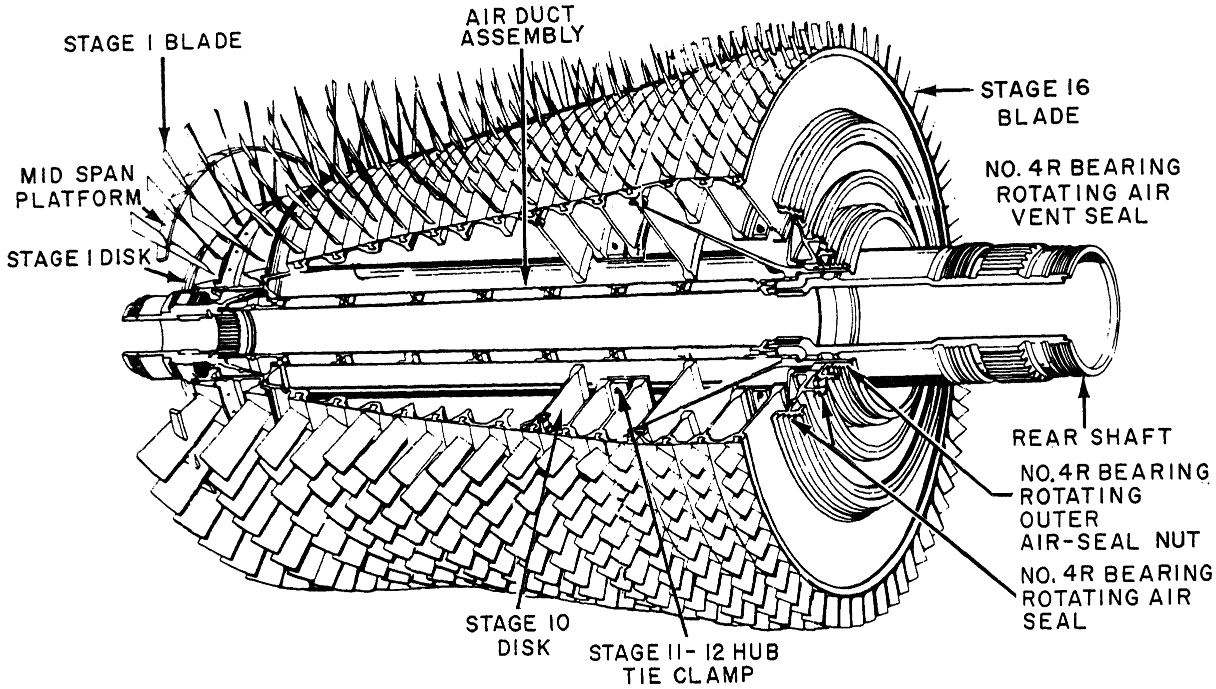

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Figure 5-6.—Compressor rotor.

eighth-stage vanes. Ninth-stage air is used for PT cooling, PT forward seal pressurization, and PT balance piston cavity pressurization. It is extracted from between the ninth-stage vanes through holes in the vane bases. Thirteenth-stage air is used for cooling the second-stage HP turbine nozzle. It is extracted from between the 13th-stage vanes through holes in the vane bases.

The variable vanes are actuated by a pair of master levers. The aft ends of the master levers are attached to pivot posts at about the 10th stage. One is on each side of the casing. Each of the master lever forward ends is positioned by a hydraulic actuator. Adjustable linkages connect directly from the master levers to actuating rings. Lever arms connect the actuating rings to the variable vanes. The variable vanes are positioned by fuel pressure from the main fuel control (MFC).

Compressor Rotor

The compressor (figure 5-6) is a spool/disk structure. Use of spools allows several stages of blades to be carried on a single piece of rotor

Table 5-1.—Compressor Blading

Stage	Number of Blades
Compressor	
1	36
2	26
3	42
4	45
5	48
6	54
7	56
8	64
9	66
10	66
11	76
12	76
13	76
14	76
15	76
16	76
High Pressure Turbine	
1	108 (54 pairs)
2	116 (58 pairs)

structure. An air duct routes eighth-stage air aft from the front frame hub area through the center of the rotor. The routing of air is for pressurization of the B sump seals. The air duct is supported by the front and rear shafts. The first-stage blades have mid span platforms to reduce blade tip vibration. Table 5-1 is a list of the number of blades in each compressor stage.

Compressor Rear Frame

The compressor rear frame consists of the outer case and the hub containing the B sump. It also has ten struts attaching the hub to the outer case. The outer case supports the combustor, the fuel manifold, 30 fuel nozzles, and two spark igniters. It also supports the first-stage HP turbine nozzle support. An internal manifold within the frame extracts air upstream of the combustion area. It routes this 16th-stage air through struts 3, 4, 8, and 9. This provides the ship's bleed air system with compressor discharge air. Six borescope ports are located in the case just forward of the mid flange. They permit inspection of the combustor, fuel nozzles, and the first-stage turbine nozzle.

Two borescope ports are provided in the aft portion of the case for inspection of the turbine blades and nozzles. The B sump contains the No. 4R and 4B bearings (R or no letter = roller, B = ball). The 4B bearing is the thrust bearing for the HP rotor system. The frame struts provide passage for lube oil, scavenge oil, sump vent, and seal leakage. Seal leakage is air leakage past the compressor discharge pressure seals. The frame struts also provide passage for bleed air for masker, prairie, anti-icing, and engine starting services. The rear frame supports the aft end of the compressor stator by the frame's forward flange. It supports the aft end of the compressor rotor by the No. 4R and 4B bearings.

LM2500 COMBUSTOR

The LM2500 combustor (figure 5-7) is an annular type and consists of four major

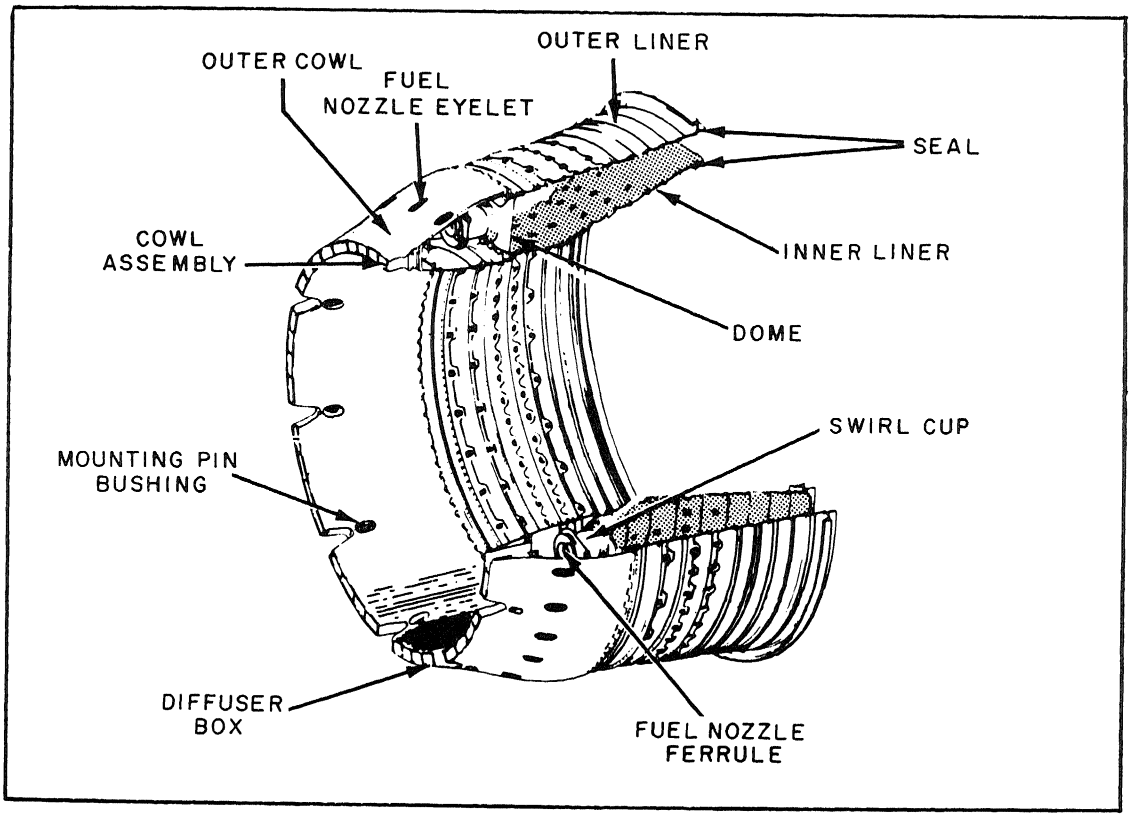

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Figure 5-7.—LM2500 combustor.

components riveted together—cowl (diffuser) assembly, dome, inner liner, and outer liner.

The cowl assembly and the compressor rear frame serve as a diffuser and distributor for the compressor discharge air. They furnish uniform airflow to the combustor throughout a large operating range. This provides uniform combustion and even-temperature distribution at the turbine. The cowl assembly consists of machined ring inner and outer cowl inlets welded to the inner and outer cowl walls. Strength and stability of the cowl ring section are provided with a truss structure. The structure consists of 40 box sections welded to the cowl walls. The box sections also serve as aerodynamic diffuser elements. The cowl assembly leading edge fits within and around the compressor rear frame struts. This arrangement provides a short overall combustor system length.

The combustor is mounted in the compressor rear frame. It is normally on ten equally spaced mounting pins in the forward (low-temperature) section of the cowl assembly. These pins provide positive axial and radial location. They assure centering of the cowl assembly in the diffuser passage. The mounting hardware is enclosed within the compressor rear frame struts so it will not affect airflow.

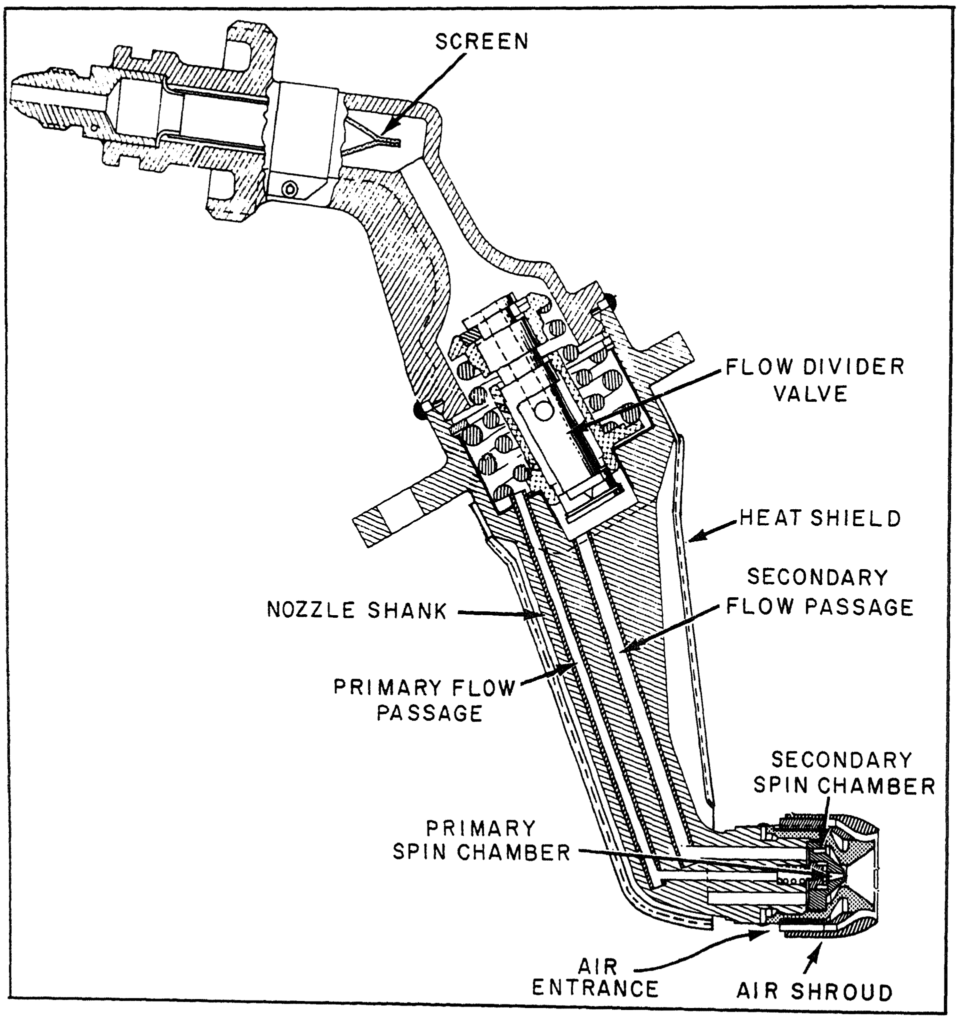

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Figure 5-8.—Fuel nozzle.

Thirty vortex-inducing axial swirl cups in the dome (one at each fuel nozzle tip) provide flame stabilization. They also mix the fuel and air. The interior surface of the dome is protected from the high temperature of combustion by a cooling air film. Accumulation of carbon on the fuel nozzle tips is prevented by venturi-shaped spools attached to the swirler.

The combustor liners are a series of overlapping rings joined by resistance-welded and brazed joints. They are protected from the high combustion heat by circumferential film cooling. Primary combustion and cooling air enters through closely spaced holes in each ring. These holes help to center the flame and admit the balance of the combustion air. Dilution holes on the outer and inner liners provide additional mixing to lower the gas temperature at the turbine inlet. Combustor/turbine nozzle air seals at the aft end of the liners prevent excessive air leakage. The seals also provide for thermal growth.

Fuel Nozzles

The fuel nozzle (figure 5-8) is a dual orifice, swirl atomizer with an internal flow divider. Fuel enters the nozzle through an individual fuel tube encased in a leak barrier (shroud) tube. The 30 fuel nozzles produce the desired spray pattern throughout the range of fuel flows.

Fuel entering the nozzle flows through a 117-micron screen and then the flow divider. When the nozzle is pressurized, primary fuel flows into a drilled passage and tube assembly in the nozzle shank. Then it goes through the primary fuel spin chamber and into the combustor. When nozzle fuel pressure rises to 330-350 psi, the flow divider opens to introduce secondary flow. Secondary fuel flows from the nozzle fuel chamber, through the flow divider, down the nozzle shank, and into the secondary fuel spin chamber. There it combines with the primary flow as it enters the combustor. A small quantity of air is scooped out of the main airstream by the shroud on the nozzle tip. This cools the nozzle tip and retards the accumulation of carbon deposits on its face.

Ignition System

The LM2500 ignition system provides the initial ignition to start combustion in the engine. There are two spark igniters located in the combustor. These are connected to the ignition exciter by the ignition leads. The ignition system is provided with 115 volt a.c. 60 Hz power from the propulsion electronics. Figure 5-9 shows a block diagram of the LM2500 ignition system.

IGNITION EXCITER.—The ignition exciters are the capacitor discharge type. They are located on the right side of the front frame. They are attached to special mounts that absorb shock and vibration. The exciters operate on 115 volt a.c. 60 Hz input. The power is transformed, rectified,

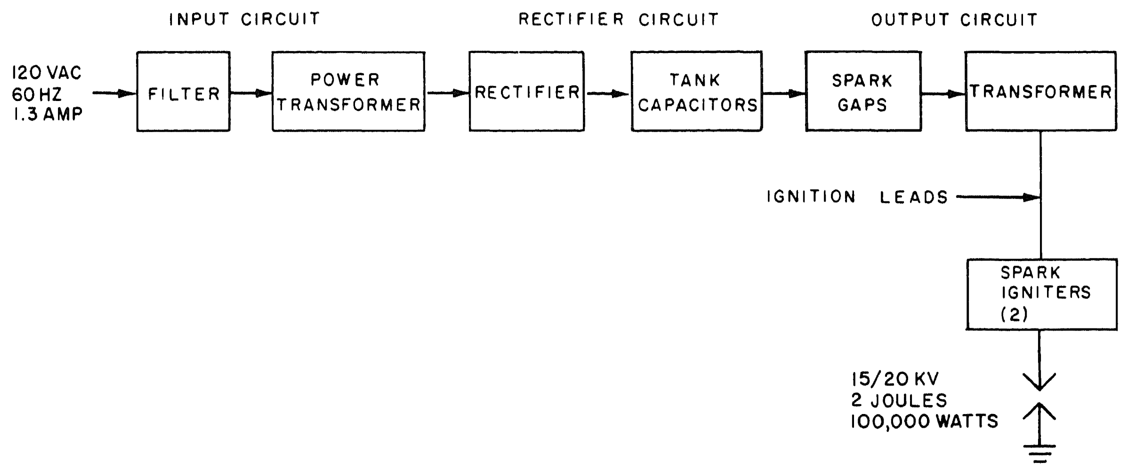

Figure 5-9.—Block diagram of the LM2500 ignition system.

and discharged in the form of capacitor discharge energy pulses. It then flows through the coaxial shielded leads to the spark igniters.

When the starting switch is closed, shipboard 60 Hz power is applied to the exciter circuits. The exciter consists of input, rectifier, discharge, and output circuits. The input circuit includes a filter that prevents feedback of radio-frequency interference (RFI) (generated within the exciter). The filter also prevents introduction of electromagnetic interference (EMI) (generated externally). The input circuit also includes a power transformer that provides step-up voltage for the rectifier circuit. The full-wave rectifier circuit includes diodes that rectify the high voltage a.c. This circuit also includes capacitors that are arranged in a voltage doubler configuration. Tank capacitors store up the d.c. voltage developed in the rectifier circuit. They store this voltage until the potential developed reaches the breakdown point of spark gaps in the discharge circuit. The discharge circuit contains the spark gaps, high-frequency (HF) capacitor, resistors, and HF transformer. When the spark gaps break down, a current (caused by a partial discharge of the tank capacitors) through the HF transformer and in conjunction with the HF capacitor causes a series resonant condition to exist. It also causes HF oscillations to occur in the output circuit. These HF oscillations cause ionization of a recessed spark gap of the igniter plug. A low-resistance path now exists for total discharge of the tank capacitor producing a high energy spark used to ignite the fuel within the combustor. The spark rate is determined by the total rectifier circuit resistance. This controls the resistance-capacitance (RC) time constant in the charging circuit.

SPARK IGNITERS.—The spark igniters (figure 5-10) are the surface gap type. They have internal passages for air cooling and air vents. These passages prevent the accumulation of carbon in interior passages. The igniter has a seating flange with attached copper gaskets for sealing purposes. Grooves in the outer surface of the tip and axial holes cool the outer and inner electrodes with compressor bleed air.

The surface gap will ionize at 8,500 volts when dry and 15,000 volts if wet. There is a discharge of two joules of energy across the gap.

CAUTION

This energy level is lethal. Output from the spark exciter, leads, or igniter should never be contacted by personnel. A grounding probe must be used to ground the ignition system when maintenance is performed.

IGNITION LEADS.—The ignition leads are low-loss connections between the ignition exciters and the spark igniters. They are coaxial, having metallic shielding that incorporates copper inner braid, sealed flexible conduit, and nickel outer braid.

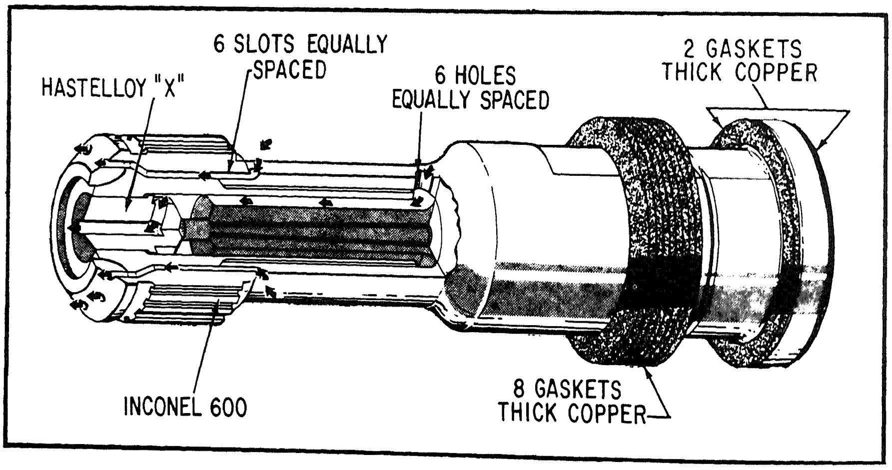

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Figure 5-10.—Spark igniter.

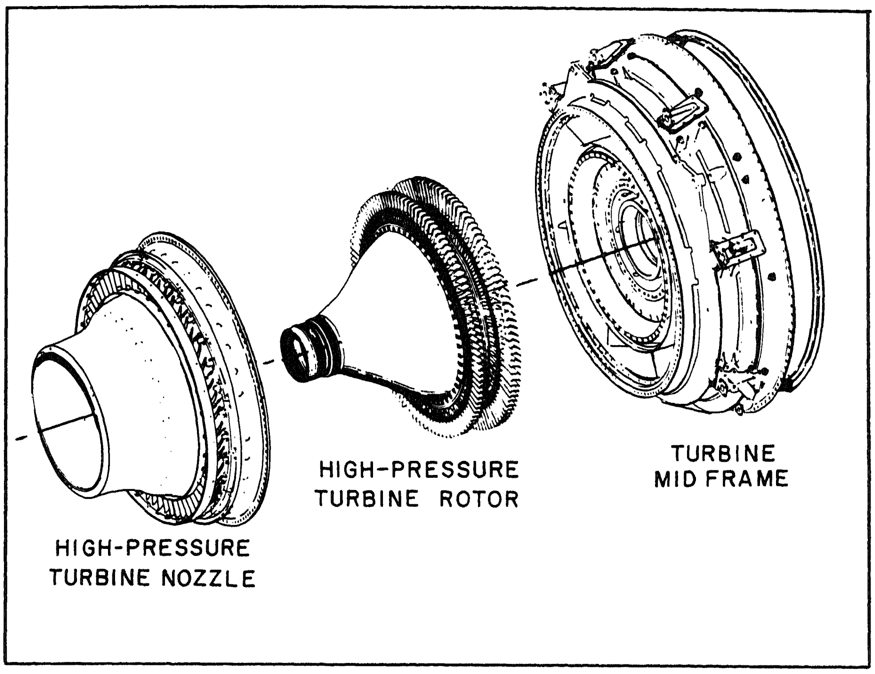

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Figure 5-11.—High-pressure turbine.

HIGH-PRESSURE TURBINE

The HP turbine section (figure 5-11) consists of the HP turbine rotor, first- and second-stage turbine nozzle assemblies, and turbine mid frame. The turbine rotor extracts energy from the gas stream to drive the compressor rotor. The turbine rotor is mechanically coupled with the compressor rotor. The turbine nozzles direct the hot gas from the combustor onto the rotor blades at the best angle and velocity.

The front end of the turbine rotor is supported at the compressor rotor rear shaft by the No. 4 bearings. The rear of the rotor is supported by the No. 5 bearing in the turbine mid frame. The turbine nozzles are contained in and supported by the compressor rear frame. The turbine mid frame, besides supporting the aft end of the turbine rotor, also supports the front end of the PT. It contains the transition duct. The gas flows throughout this duct from the HP turbine section into the PT.

High-Pressure Turbine Rotor

The HP turbine rotor (figure 5-12) has a conical forward shaft and two disks with blades and

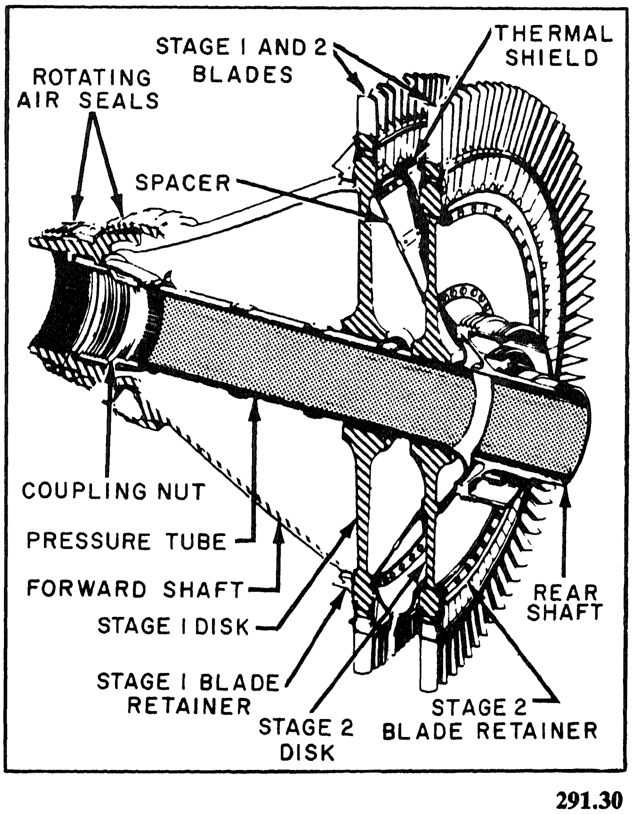

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Figure 5-12.—High-pressure turbine rotor.

retainers. It also has a conical rotor spacer, a thermal shield, and a rear shaft.

The forward turbine shaft transmits energy to the compressor rotor. Two seals are on the forward end of the shaft. The front seal helps prevent compressor discharge pressure (CDP) air from entering the B sump. The other seal maintains CDP in the plenum formed by the rotor and the combustor. This plenum is a balance chamber that provides a corrective force that minimizes the thrust load on the No. 4B bearing.

Turbine blades in both stages are long shanked and internally air cooled. Use of long-shank blades provides thermal isolation of dovetails, cooling air flow paths, high damping action for low vibration, and low disk rim temperature. The blades are brazed together in pairs. The turbine blades are coated to improve erosion and oxidation resistance.

HIGH-PRESSURE TURBINE ROTOR COOLING.—The HP turbine rotor (figure 5-13) is cooled by a continuous flow of compressor discharge air. This air passes through holes in the first-stage nozzle support and forward turbine shaft. The air cools the inside of the rotor and both disks before passing between the paired dovetails and out to the blades.

HIGH-PRESSURE TURBINE BLADE COOLING.—Both stages of HP turbine blades (figure 5-14) are cooled by compressor discharge air. This air flows through the dovetail and through blade shanks into the blades. First-stage blades are cooled by internal convection and external film cooling. The convection cooling of the center area is done through a labyrinth within the blade. The leading edge circuit provides internal convection cooling by airflow through the labyrinth. Then air flows out through the leading edge tip and gill holes. Convection cooling of the trailing edge is provided by air flowing through the trailing edge exit holes. Second-stage blades are cooled by convection, with all the cooling air discharged at the blade tips.

High-Pressure Turbine Nozzles

High-pressure turbine nozzles are installed in two sets, the first stage and the second stage. As there are significant differences between the two stages, we will discuss them separately.

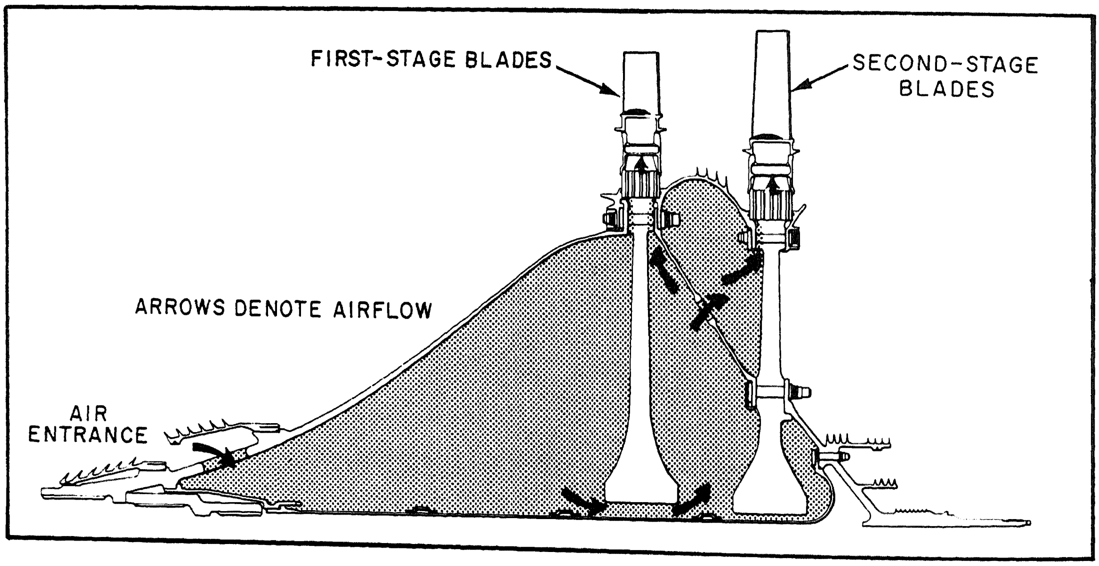

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Figure 5-13.—High-pressure turbine rotor cooling.

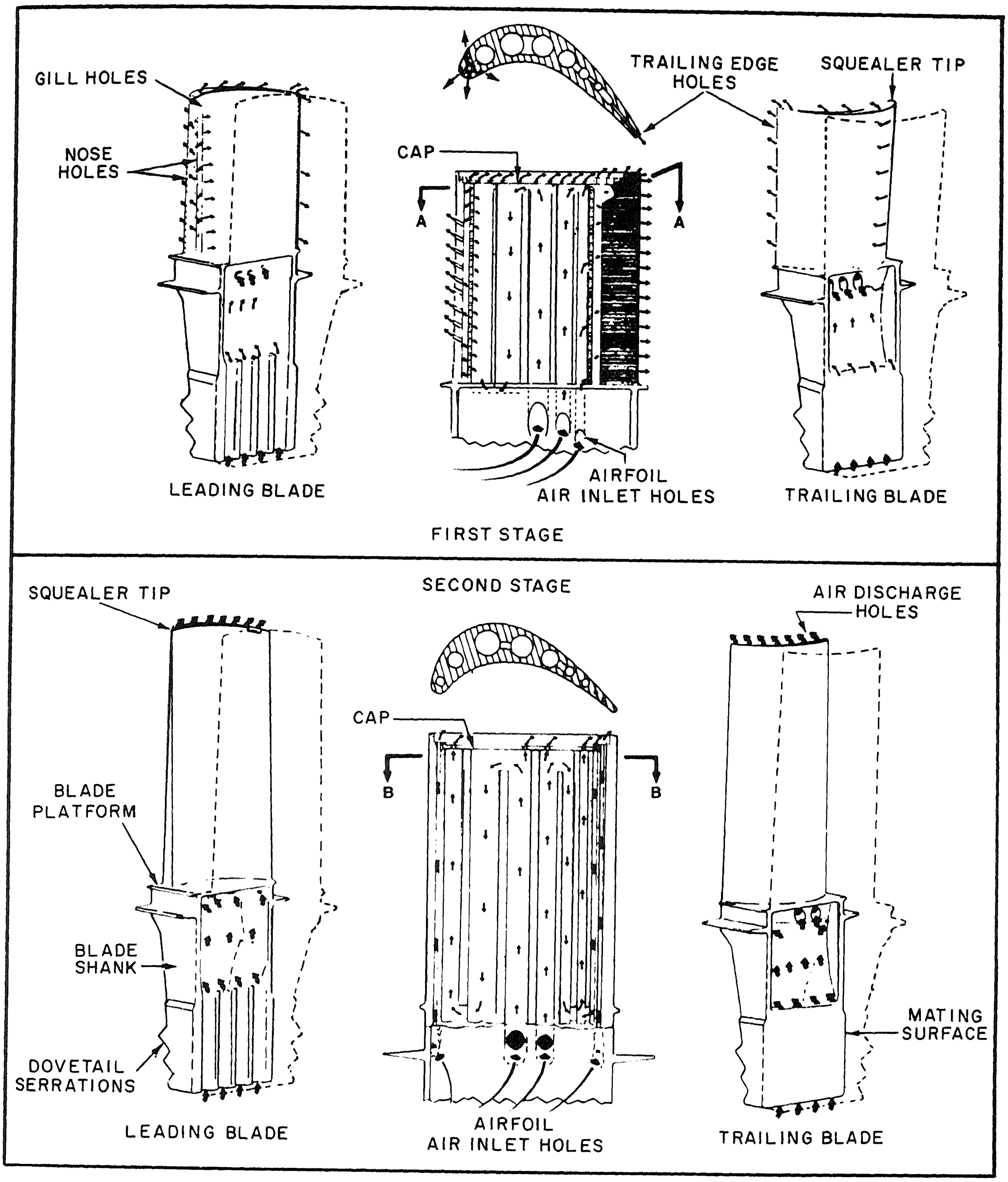

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Figure 5-14.—High-pressure turbine rotor blade cooling.

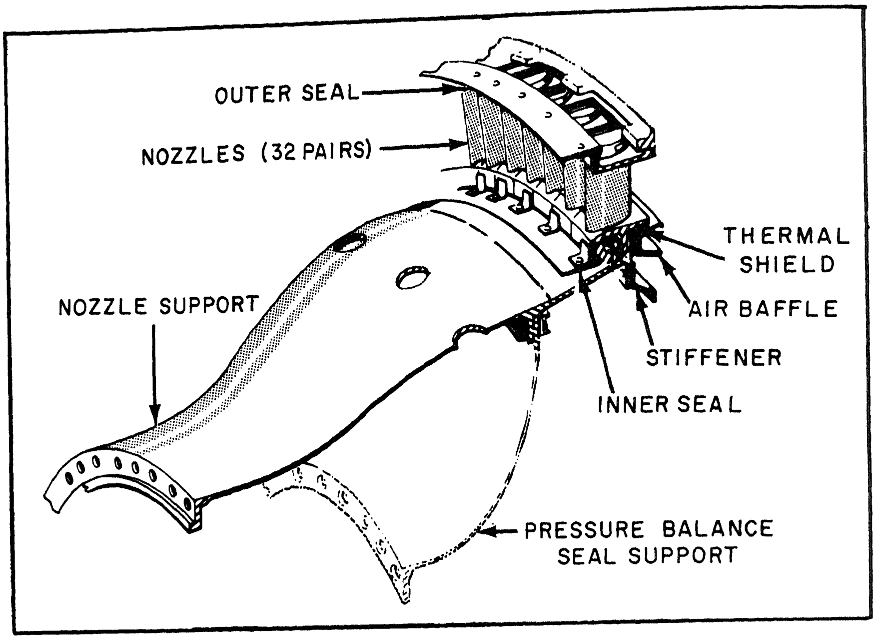

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Figure 5-15.—First-stage high-pressure turbine nozzle.

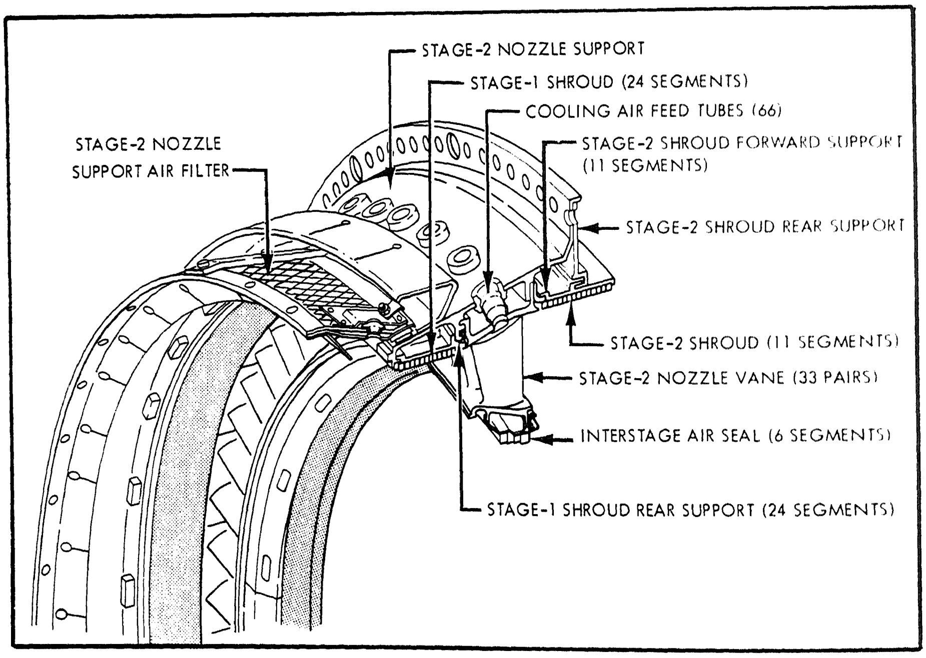

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Figure 5-16.—Second-stage high-pressure turbine nozzle.

FIRST-STAGE TURBINE NOZZLE ASSEMBLY.—The major parts of the first-stage turbine nozzle assembly (figure 5-15) are the nozzle support, nozzles, inner seal, outer seal, and baffles. The nozzles are coated to improve erosion and oxidation resistance. They are bolted to the first-stage nozzle support. They receive axial support from the second-stage nozzle support. There are 32 nozzle segments in the assembly. Each segment consists of two vanes. The vanes are cast and then welded into pairs (segments) to decrease the number of gas leakage paths. The first-stage nozzles are cooled by air from the compressor's 16th stage.

SECOND-STAGE TURBINE NOZZLE ASSEMBLY.—The major parts of the second-stage nozzle assembly (figure 5-16) are the nozzles, nozzle support, stage-1 and stage-2 turbine shrouds, and interstage seal.

The nozzle support is a conical section. It has a flange that is bolted between the flanges of the compressor rear frame and the turbine mid frame. The support mounts the nozzles, cooling air feeder tubes, and the stage-1 and stage-2 turbine shrouds.

The nozzles are cast and then coated. The vanes (two per nozzle) direct the gas stream onto the second-stage turbine blades. The inner ends of the nozzles form a mounting circle for the interstage seal attachment.

The turbine shrouds form a portion of the outer aerodynamic flow path through the turbine. They are located radially in line with the turbine blades. The turbine shrouds form a pressure seal to prevent excessive gas leakage over the blade tips. The sealing (rubbing) surface is nickel-aluminide compound. Stage 1 has 24 segments; stage 2 has 11 segments.

The interstage seal has six segments bolted to the nozzles. It minimizes the gas leakage between the stage-2 nozzle and the turbine rotor. The sealing surface has four steps for maximum effectiveness of each sealing tooth. The seals are pregrooved to preclude seal rub under emergency shutdown conditions. The second-stage nozzles are cooled by 13th-stage bleed air.

Turbine Mid Frame

The turbine mid frame (figure 5-17) supports two areas. It supports the aft end of the HP

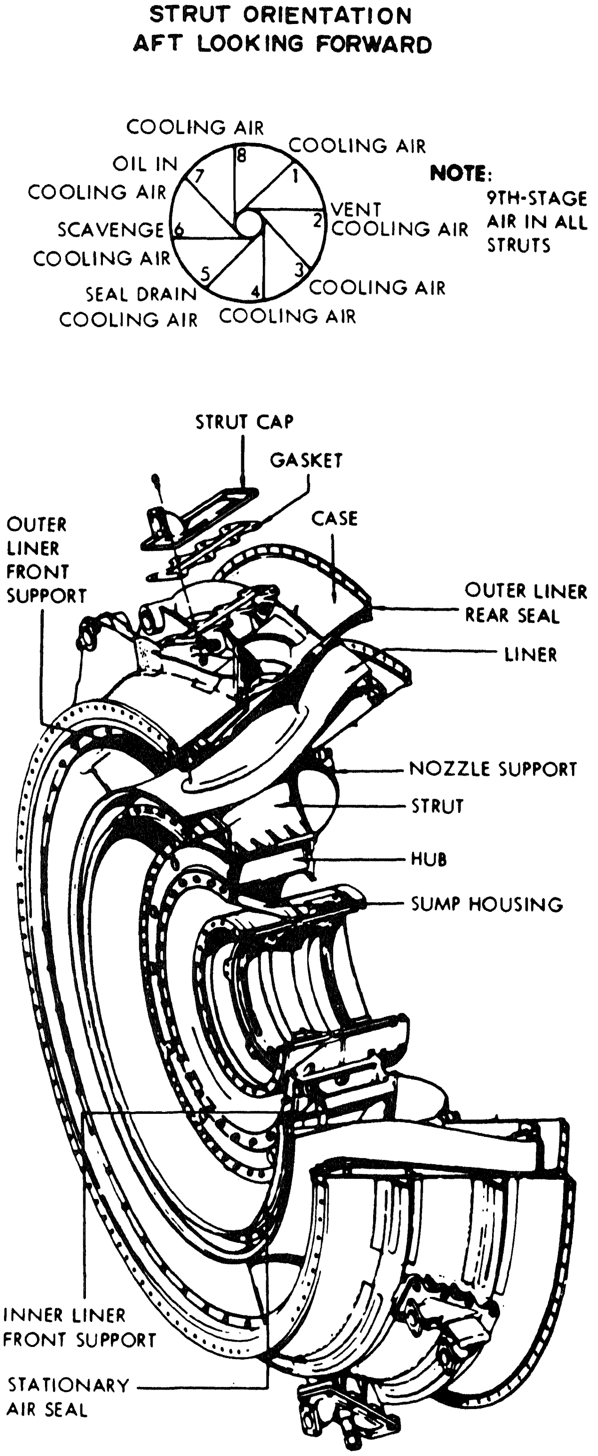

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Figure 5-17.—Turbine mid frame.

turbine rotor and the forward end of the PT rotor. It is bolted between the rear flange of the compressor rear frame and the front flange of the PT stator. The frame provides a smooth diffuser flow passage for HP turbine discharge air into the PT. Piping for bearing lubrication and seal pressurization is located within the frame struts. The frame has ports for the HP turbine exhaust thermocouples and pressure probes. These ports also provide access for borescope inspection of the PT inlet area. The PT first-stage nozzle assembly is part of the frame.

POWER TURBINE

The PT (figure 5-18) is used to extract the remaining energy from the hot gas. This energy is used to power the ship for propulsion. The PT consists of three components: the rotor, the stator, and the turbine rear frame. The PT is a separate unit from the GG. If the GG must be changed out, it is unbolted from the PT and removed separately. To remove the PT, though, you have to also remove the GG.

Power Turbine Rotor

The PT rotor (figure 5-19) consists of six disks, each having integral spacers. Each disk spacer is attached to the adjacent disk by close-fitting bolts. The front shaft is secured between stages-2 and -3 spacers. The rear shaft is secured between stages-5 and -6 spacers.

Blades of all six stages have interlocking tip shrouds for low vibration levels and are retained in the disks by dovetails. Replaceable rotating seals are secured between the disk spacers. They mate with stationary seals to prevent excessive gas leakage between stages.

Power Turbine Stator

The PT stator (figure 5-19) has two casing halves, stages-2 through -6 turbine nozzles, and six stages of blade shrouds. The stage-1 nozzle is part of the turbine mid frame assembly. Stages-2 and -3 nozzles have welded segments of six vanes each. Stages-4, -5, and -6 nozzles have segments of two vanes each.

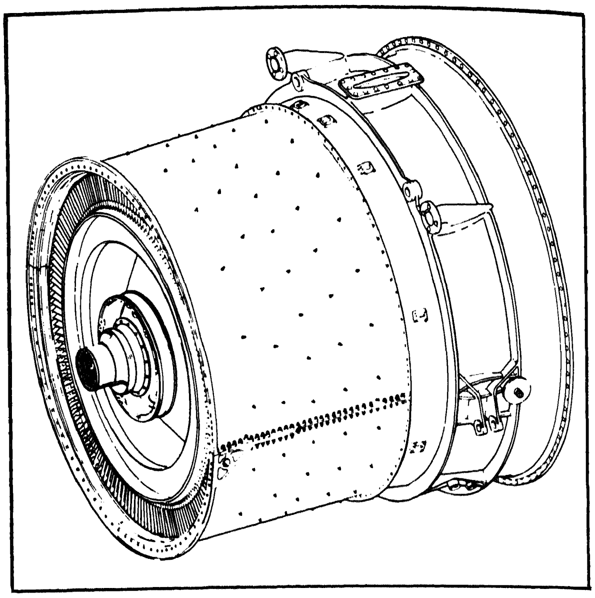

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Figure 5-18.—LM2500 power turbine.

Turbine Rear Frame

The turbine rear frame (figure 5-20) has an outer casing, eight equally spaced radial struts, and a single-piece cast steel hub. It forms the PT exhaust flow path and supports the aft end of the PT. It also supports the forward end of the high-speed flexible-coupling shaft. The turbine rear frame hub supports the inner deflector of the exhaust system. It also has a bearing housing for the No. 7B and No. 7R bearings. The hub and the bearing housings have flanges to which air and oil seals are attached to form the D sump. The frame casing supports the outer cone of the exhaust system and provides attaching points for the gas turbine rear supports. The struts have service lines for lubrication, scavenge, and vent. The PT speed pickups also pass through the struts.

ACCESSORY DRIVE SECTION

The accessory drive section (figure 5-21) has three components. These are the inlet gearbox, a radial drive shaft, and a transfer gearbox. The inlet gearbox is located in the hub of the front frame; the radial drive shaft is inside the front

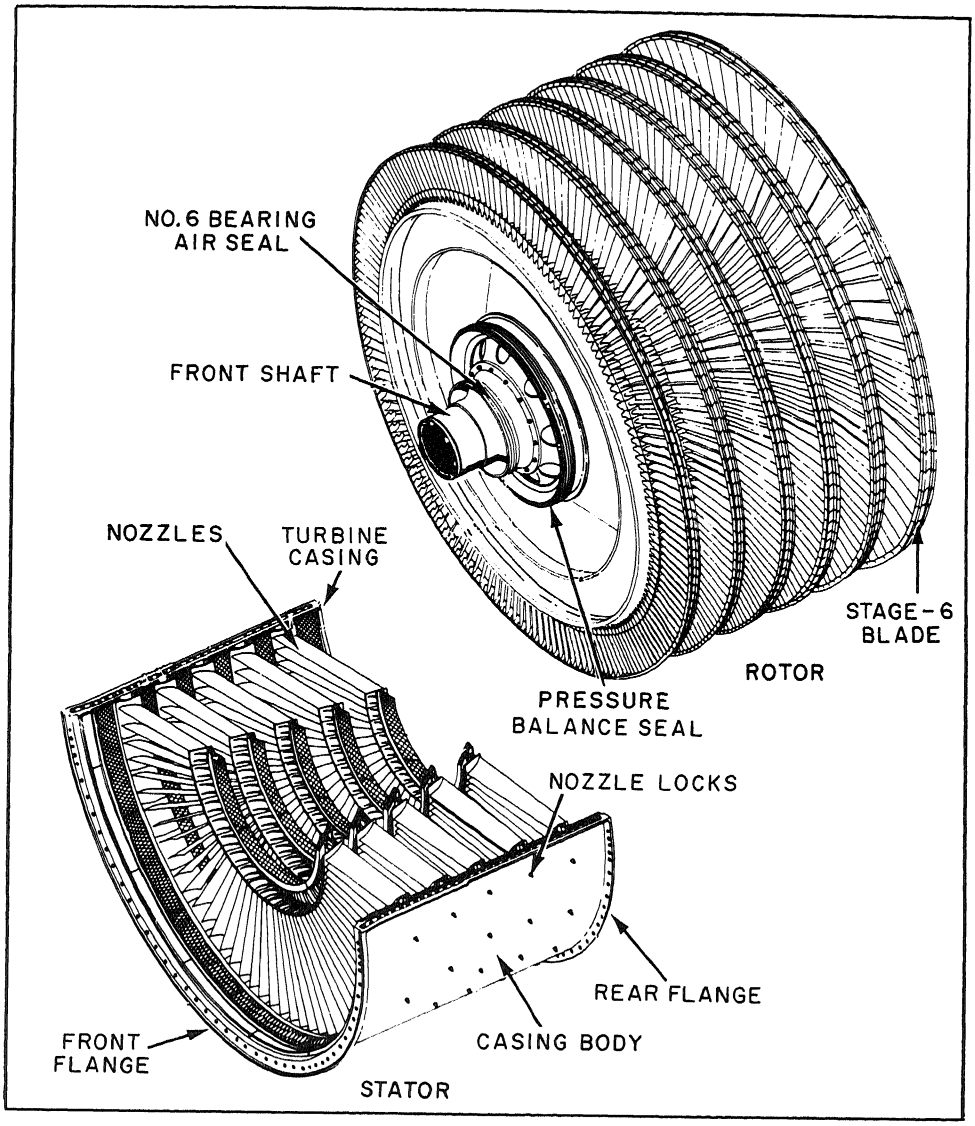

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Figure 5-19.—Power turbine rotor and stator.

frame 6 o'clock strut; the transfer gearbox is bolted underneath the front frame. The accessory drive section provides the drive train for the fuel pump with main fuel control, the lube and scavenge pump, and the pneumatic starter. It also provides mounting for the GG speed pickup. These are all mounted on the aft side of the aft transfer gearbox (accessory gearbox). An air/oil separator mounted on the front is part of the gearbox. Power to drive the accessories is extracted from the compressor rotor through a large-diameter hollow shaft. This is spline-connected to the rotor front shaft. A set of bevel gears in the inlet gearbox transfers this power to the radial drive shaft. This, in turn, transmits the power to another set of bevel gears in the forward section of the transfer gearbox. A short horizontal drive shaft transmits the power to the accessory drive adapters in the aft section of the transfer gearbox.

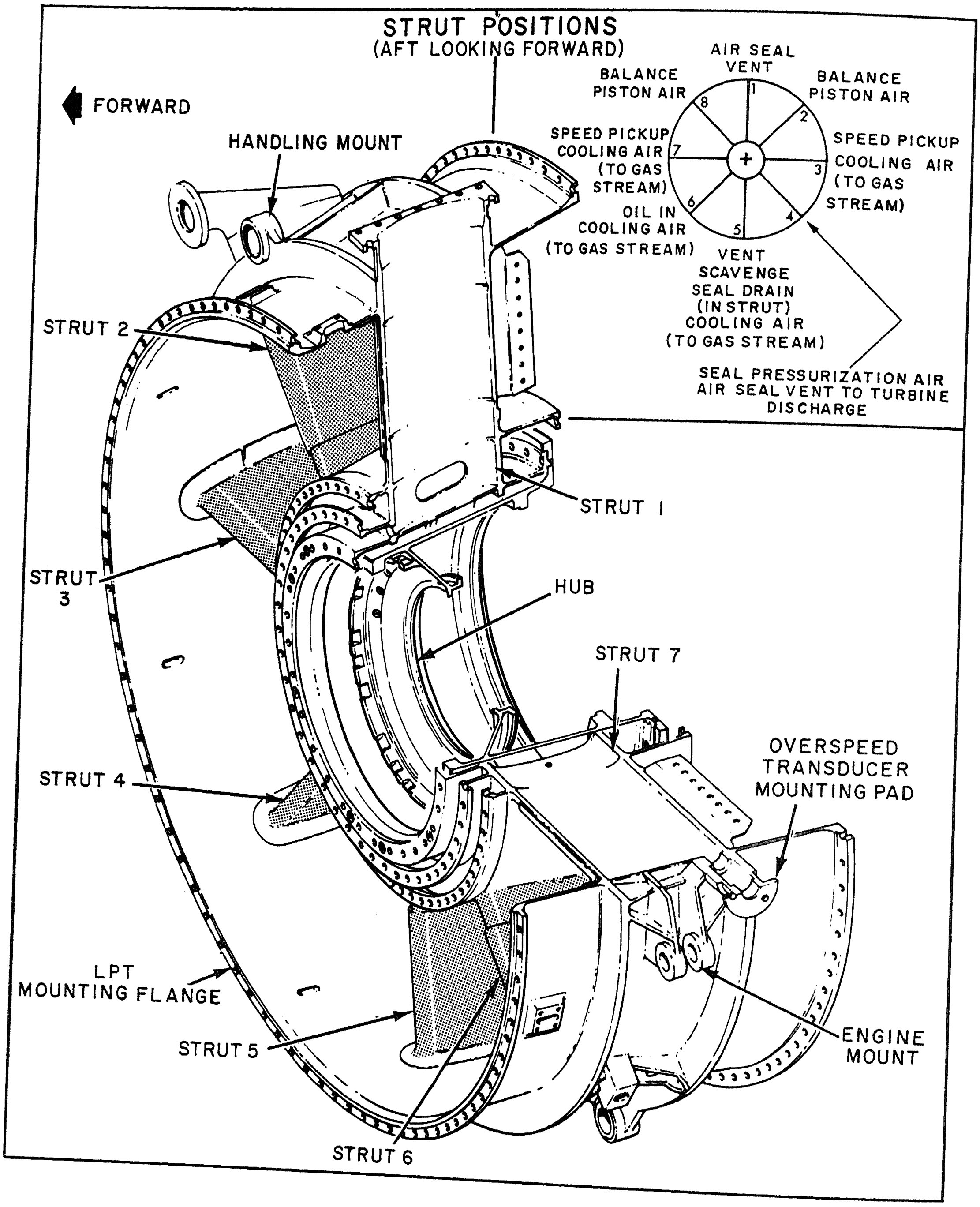

Figure 5-20.—Power turbine rear frame.

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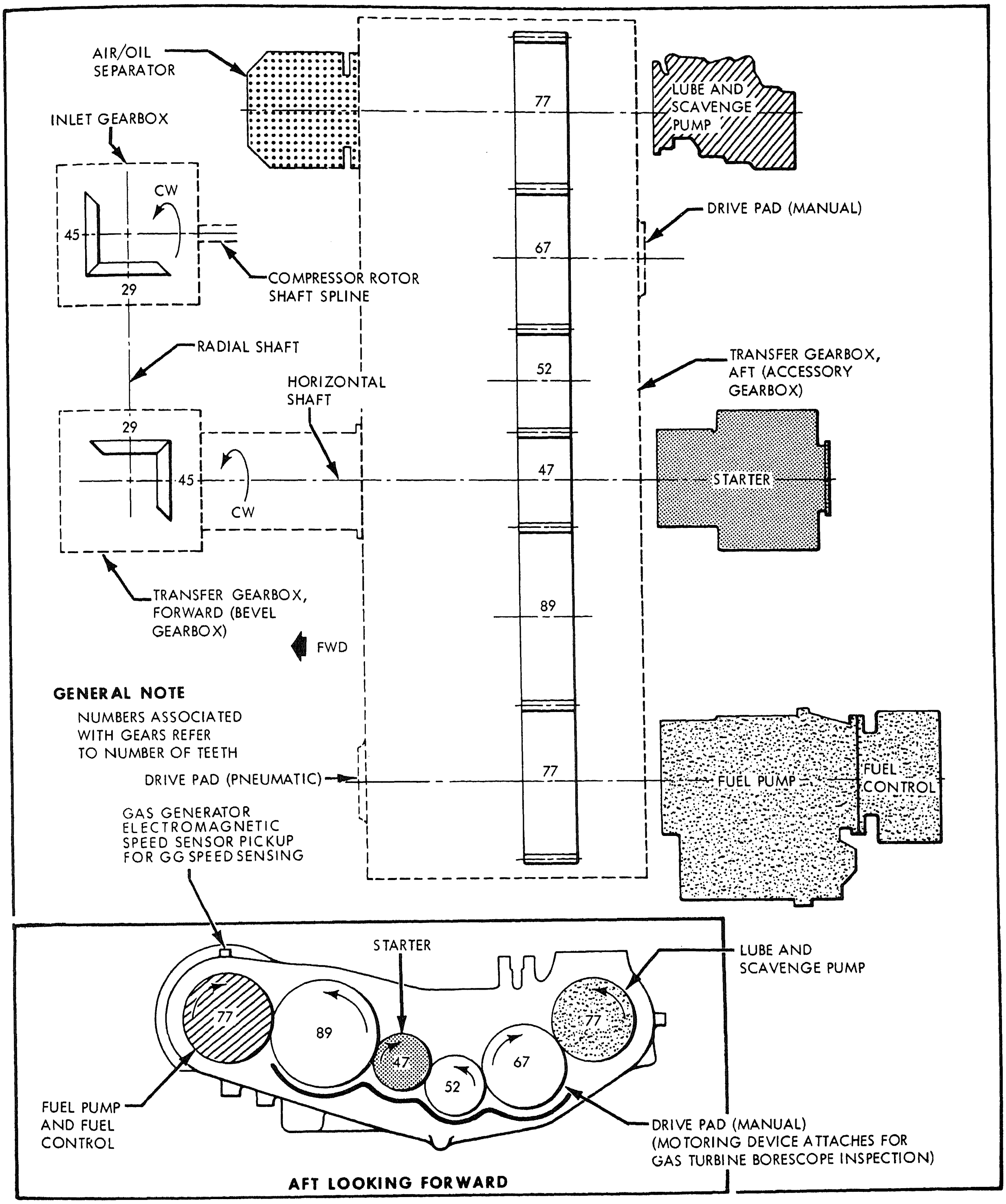

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Figure 5-21.—Accessory drive section.

Inlet Gearbox

The inlet gearbox (figure 5-22) has a cast aluminum casing, a shaft, a pair of bevel gears, bearings, and oil jets. The casing, bolted inside the compressor front frame hub, mounts two duplex ball bearings and a roller bearing. Internal oil passages and jets provide lubrication for the bearings and gears. The shaft rotates on a horizontal axis. It is splined at the aft end to mate with the compressor rotor front shaft. The shaft is supported by a duplex ball bearing. It mounts the upper bevel gear on the forward end. The lower bevel gear rotates on a vertical axis. It is supported at its upper end by a roller bearing. It is supported at its lower end by a duplex ball bearing. The lower end is splined to mate with the radial drive shaft.

Radial Drive Shaft

The radial drive shaft is a hollow shaft externally splined at each end. It mates with bevel gears in the inlet and transfer gearboxes.

Transfer Gearbox

The transfer gearbox assembly (figure 5-23) has a two-piece aluminum casing, an air/oil separator, gears, bearings, seals, oil nozzles, and accessory adapters. The forward section contains a set of right-angle bevel gears and a horizontal drive shaft. The drive shaft transmits power to the gear train in the aft section. The accessories are the fuel pump, main fuel control, lube and scavenge pump, air/oil separator, and starter. They are mounted on the aft section. For this reason, the aft section of the transfer gearbox is also called the accessory gearbox. These accessories will be described later in this chapter when we discuss the engine systems. The plug-in gear concept is used on all accessory adapters and idler gears in the aft section. This permits replacement of entire gear, bearing, seal, and adapter assemblies without disassembling the gearbox. Lubrication of the gears and bearings is provided by internal tubes and jets. The transfer gearbox is assembled as a single unit and is bolted to the engine externally. Thus, you can replace the

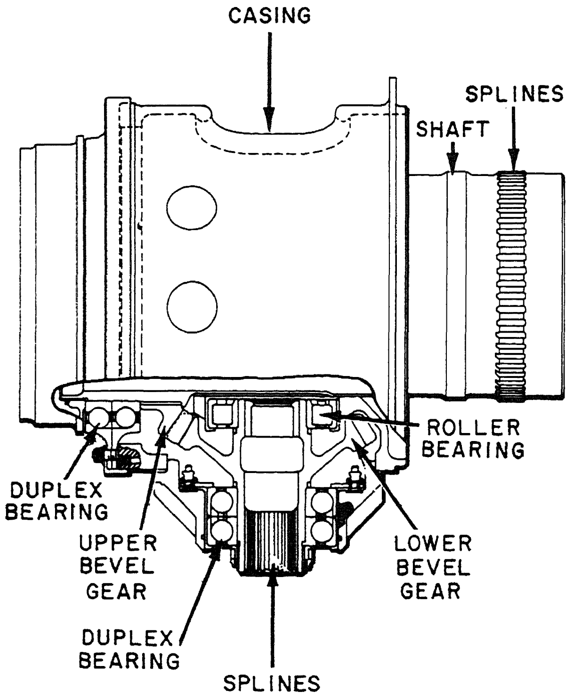

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Figure 5-22.—Inlet gearbox.

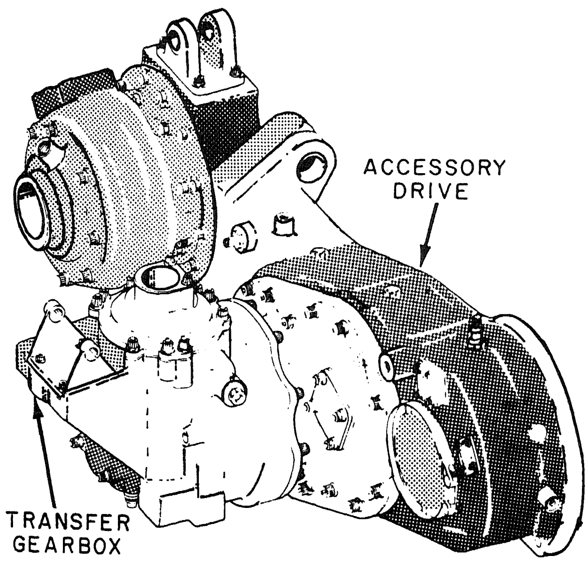

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Figure 5-23.—Transfer gearbox and accessory drive.

entire unit without removing the engine from the enclosure.

LM2500 FUEL SYSTEM

The fuel and speed covering system of the LM2500 regulates and distributes fuel to the combustor section of the engine. This fuel is used to control the speed of the GG. The PT speed is not directly controlled by the fuel. It is controlled by the amount of energy in the hot gas that is extracted by the PT. The fuel used by the LM2500 is supplied by the engine room fuel system. You can find more information on your ship's fuel system in the Engineering Operational Sequence System (EOSS).

The fuel system of the LM2500 has several components. These components are the fuel pump, main fuel control, a pressurizing valve, two fuel shutdown valves, and 30 fuel nozzles. Also included are the CIT sensor, the VSV actuator, the fuel manifold pressure transducer, the purge valve, and the fuel manifold and shroud. We will discuss each of these components individually and explain how they relate to the system. Refer to figure 5-24 which shows the flow path of the fuel to each of these components.

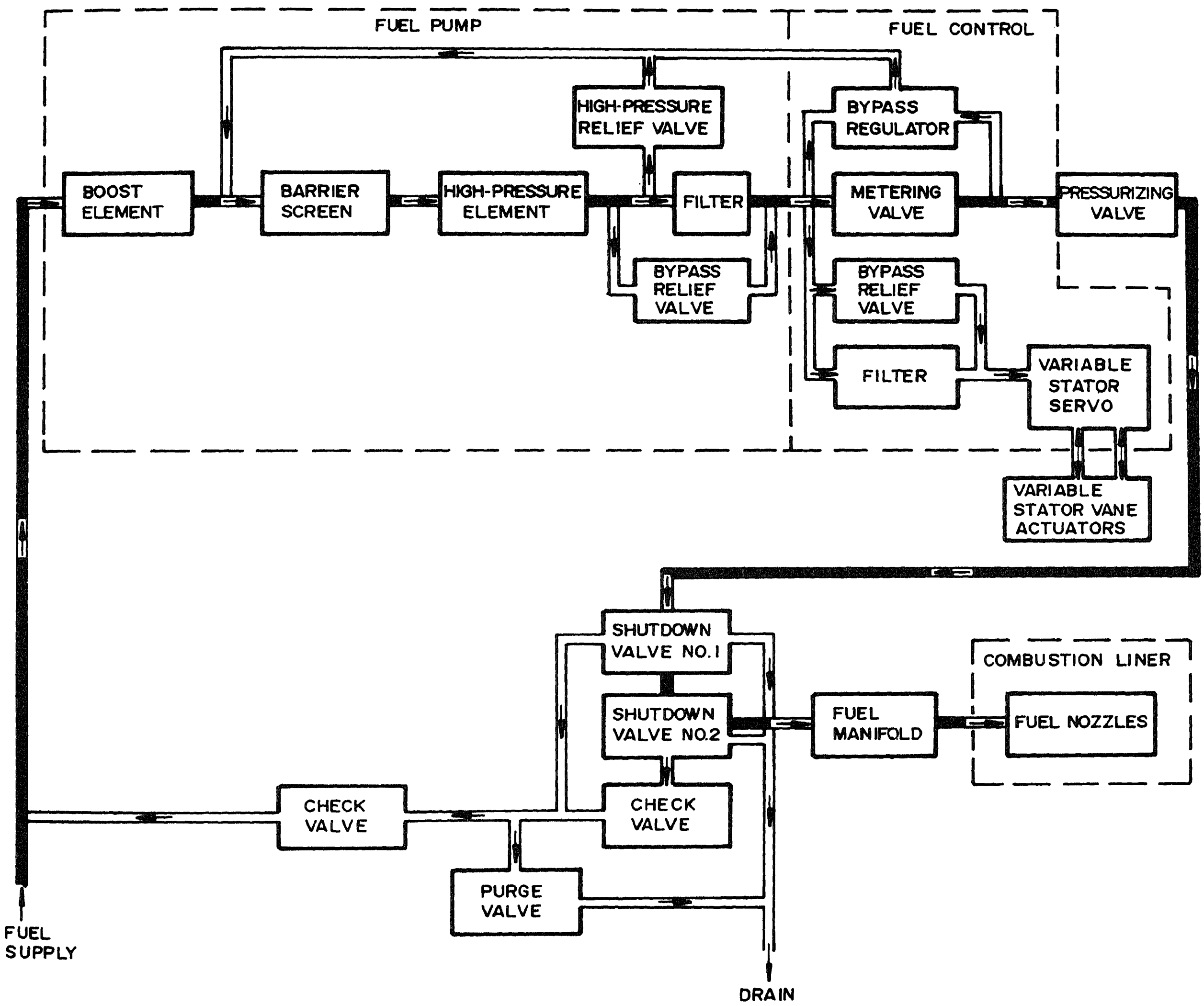

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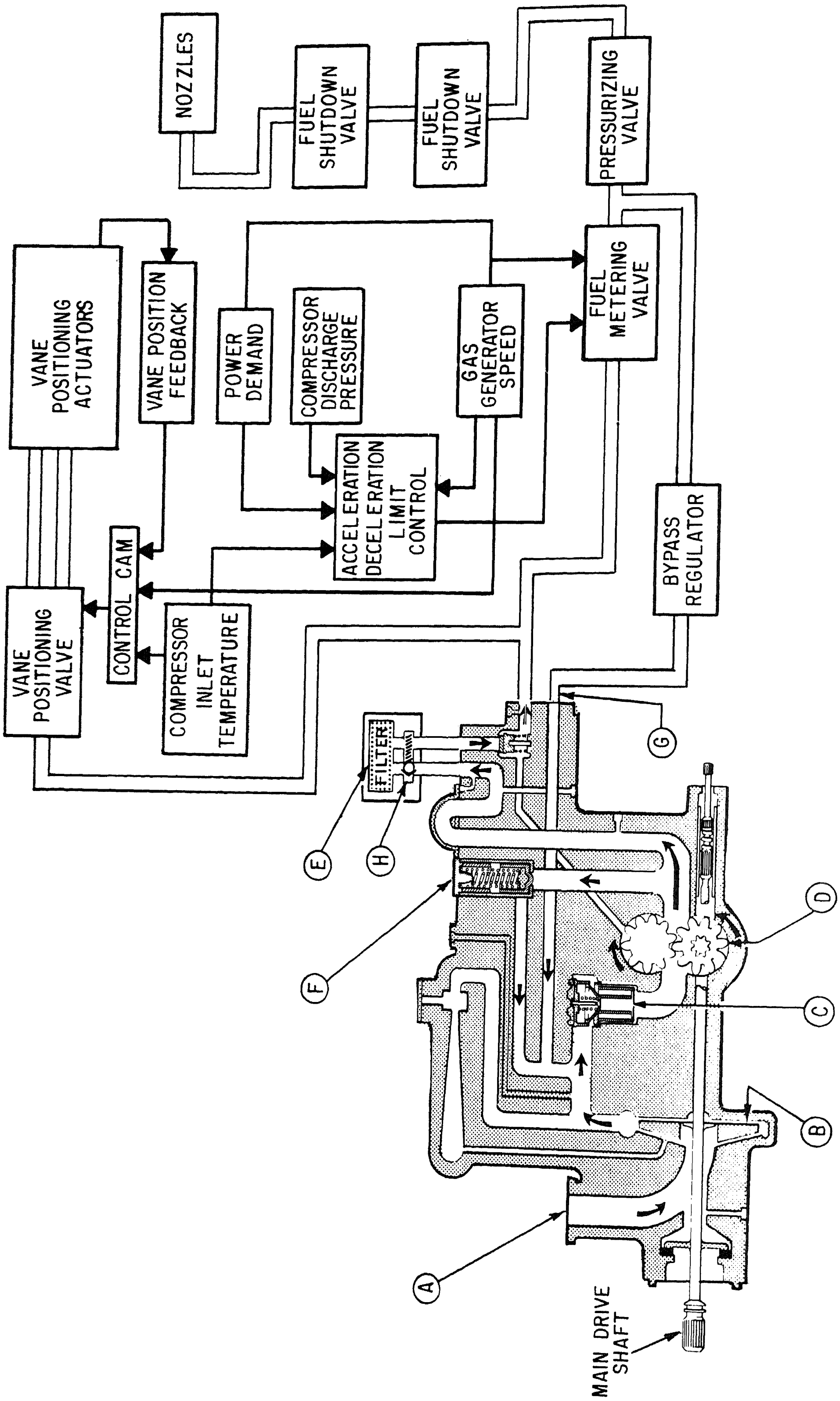
Figure 5-24.—LM2500 fuel system block diagram.



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A. FUEL INLET
B. CENTRIFUGAL PUMPING ELEMENT
C. STRAINER ELEMENT
D. HIGH-PRESSURE FUEL PUMP
E. FILTER
F. RELIEF VALVE
G. FUEL PASSAGE
H. BYPASS VALVE

Figure 5-25.—LM2500 fuel pump and system interrelation.

FUEL FLOW

Fuel supplied by the fuel oil service system flows through the base inlet connector to the fuel pump boost element. From the boost element it passes through the pump HP element. Then it goes through a pump-mounted simplex filter to the MFC. A filter bypass valve allows fuel to bypass a clogged filter.

The fuel pump has a higher flow capacity than the gas turbine uses to assure an adequate supply of fuel for gas turbine operation. The fuel is divided within the control into metered flow and bypass flow. This division is done by a bypass valve as it maintains a preset pressure drop across the metering valve. Bypass fuel is ported to the HP element inlet screen of the fuel pump. An abnormal condition can occur that causes pump outlet pressure to become too high. To correct this condition a relief valve in the pump bypasses fuel back to the HP element inlet screen.

A pressurizing valve is mounted on the fuel control outlet port. It maintains back pressure to ensure adequate fuel pressure for control servo operation. Two electrically operated fuel shutdown valves connected in series provide a positive fuel shutoff. When the fuel shutdown valves are open, metered fuel for gas turbine operation flows from the fuel control. It then flows through the pressurizing valve, shutdown valves, fuel manifold, and fuel nozzles. When the fuel shutdown valves are closed, metered fuel is bypassed to the fuel pump inlet. Then the fuel drain ports in the valves open to allow fuel in the manifold, nozzles, and lines to drain. Thirty fuel nozzles project through the compressor rear frame into the combustor. They produce an effective spray pattern from start to full power.

FUEL PUMP

The fuel pump (figure 5-25) has a centrifugal boost element and an HP gear element. It provides mounting pads and flange ports for the fuel filter and the MFC. As mentioned above, the filter bypass valve will allow fuel to bypass a clogged filter.

MAIN FUEL CONTROL

The MFC (figure 5-26) has two primary functions. One is to control GG speed (schedules

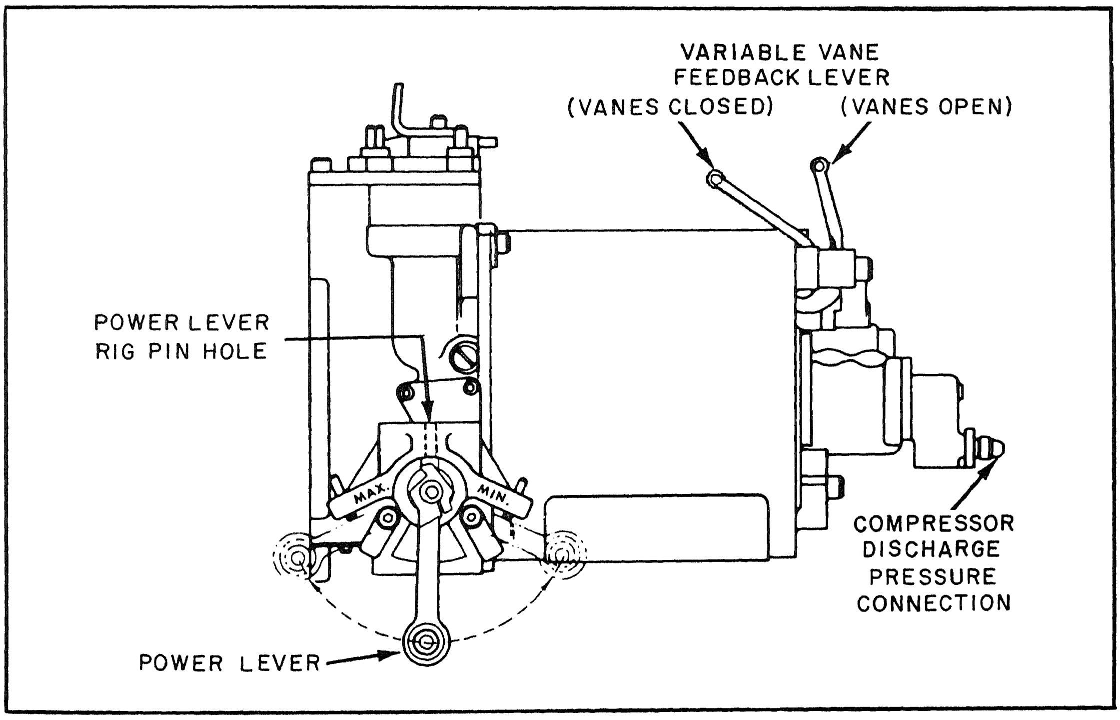

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Figure 5-26.—Main fuel control.

acceleration fuel flow, deceleration fuel flow). The other controls stator vane angle (for stall-free, optimum performance over the operating range of the gas turbine).

The MFC controls GG speed as a function of power lever position. The power lever is set electrically by a signal from the FSEE. Movement of the power lever changes speed demand. GG speed is sensed by means of a flyweight governor. This adjusts the fuel flow as necessary to maintain the speed set by the power lever. Three fuel schedules are established by the control: acceleration, deceleration, and minimum fuel schedules. The acceleration schedule limits fuel flow necessary for acceleration to prevent overtemperature and stall. The deceleration schedule limits the rate of fuel flow decrease to prevent combustion flameout during deceleration. The minimum fuel schedule limits fuel flow for starting to prevent overtemperature. The control senses CIT, CDP, and engine speed (N_{GG}). This biases the fuel schedules as a function of atmospheric and engine operating conditions.

The MFC schedules the VSVs as a function of GG speed and CIT. Actual position of the VSVs is sensed by the control via a position feedback cable. One end of the feedback cable is connected to the left master lever arm. The other end is connected to the feedback lever on the MFC.

PRESSURIZING VALVE

The pressurizing valve pressurizes the fuel system. This provides adequate fuel control servo supply pressure and VSV actuation pressure. This is necessary for proper fuel and stator vane scheduling during GG operation at low fuel flow levels. The valve is a fuel pressure-operated, piston-type valve. The piston is held on its seat (closed) by spring force and fuel pressure (reference pressure) from the MFC. Servo pressure is 110 to 275 psig. MFC discharge fuel (metered fuel for combustion) enters the pressurizing valve at the opposite side of the piston. When MFC discharge pressure is 80 to 130 psig greater than reference pressure, the valve opens. Thus, the upstream pressure (including servo supply and stator actuation) is 190 psig or greater before the pressurizing valve opens. This is adequate for proper operation.

FUEL SHUTDOWN VALVES

The fuel shutdown valves are pilot-valve actuated and electrically controlled. The valves are piped hydraulically in series. They are electrically operated in parallel by control logic during an automatic sequence. You can manually operate them from a local control panel during a manual stop. Both valves must be energized to port metered fuel to the GG fuel manifold. De-energizing either valve will bypass the fuel back to the pump inlet. Normally, both valves are de-energized to shut down the engine. The second valve acts as a backup and will bypass fuel if the first should fail to function. You can operate the two valves independently from the local operating panel (LOP) as a maintenance check. The fuel manifold system is shrouded. (The manifold and the manifold-to-fuel nozzle connector tubes are tubes within a tube assembly.) If a fuel leak develops in the manifold system, the leakage collects inside the shroud. It is then drained through a drain line to a telltale drain under the enclosure base. Next it goes to a collection tank. Thus, fuel leakage inside the enclosure from the manifold system is prevented and fire hazard is minimized.

COMPRESSOR INLET TEMPERATURE SENSOR

The CIT sensor consists of a constant-volume, gas-filled probe and a metering valve. This sensor controls or meters fuel across an orifice. It is mounted at the 8 o'clock position in the compressor front frame. The sensing probe projects through the frame into the airstream. Since the temperature sensing probe has a constant volume, the gas pressure inside the probe is equal to the temperature. This pressure is connected to a sensing bellows, which, in turn, is connected to the metering valve. Fuel from the MFC enters the CIT sensor. There it is metered by the metering

valve proportional to the temperature at the sensing probe. It is then used as a scheduling parameter by the MFC.

VARIABLE STATOR VANE ACTUATORS

The VSV actuators are single-ended, uncushioned hydraulic cylinders. They are driven in either direction by HP fuel. Piston stroke is controlled by internal stops. The actuators are mounted on either side of the compressor stator forward flange at the 3 and 9 o'clock positions. They are connected to the VSVs through master lever arms and actuation rings. The MFC schedules HP fuel to either the head end port (opens VSVs) or the rod end port (closes VSVs). The MFC senses several parameters to schedule variable vane angle. These are N_{GG}, CIT, and stator vane angle. A feedback cable is connected on one end to the left master lever arm and on the other end to the MFC. It inputs stator vane angle.

FUEL PURGE VALVE

The purge valve is an electrically operated, normally closed, on-off valve. It is used to drain low-temperature fuel from the system before gas turbine start. You can operate it by control logic during an automatic sequence or manually when a purge is required.

FUEL NOZZLES

The LM2500 uses 30 fuel nozzles to admit fuel to the combustor. These nozzles were discussed in depth earlier in this chapter. Refer to the section on the combustor for a complete description of fuel nozzles.

FUEL MANIFOLD PRESSURE TRANSDUCER

The fuel manifold pressure transducer is used to input the fuel manifold pressure into the FSEE. This input is used to display the pressure at the operating consoles.

The transducer is a 0 to 1500 psig model. It is located under the module on the baseplate. Fuel is supplied to the transducer from the fuel line leading to the fuel manifold. This is a standard-type transducer like that described in chapter 3.

LUBE OIL SYSTEM

The lubrication system (figure 5-27) provides the gas turbine bearings, gears, and splines with adequate cool oil. This prevents excessive friction and heat. The synthetic lube oil used in this application is MIL-L-23699. The lubrication system is a dry sump system. It is divided into three subsystems that have three functions identified as lube supply, lube scavenge, and sump vent.

The lube oil system contains several components which perform the functions of the subsystem. These components are the lube and scavenge pump, the supply filter, the supply check valve, and the C and D sump supply check valves. These units are all mounted either on the engine or in the enclosure. Some components are mounted on the lube oil storage and conditioning assembly (LOSCA) (figure 5-28). These units are the oil tank, oil cooler, scavenge oil filter, scavenge oil check valve, filter differential pressure transducer and gauge, level sensor, and temperature switch.

LUBE OIL FLOW

Lube oil is gravity fed from the LOSCA through the ship's piping to an inlet fitting in the enclosure base. It is then fed to the inlet of the supply element of the lube and scavenge pump. From the supply element of the pump, the oil passes through the supply duplex filter. It then goes through a check valve and into a supply manifold. From the supply manifold, the oil is distributed to the four sumps and the transfer gearbox. Each end of the sump has a labyrinth/windback oil seal and a labyrinth air

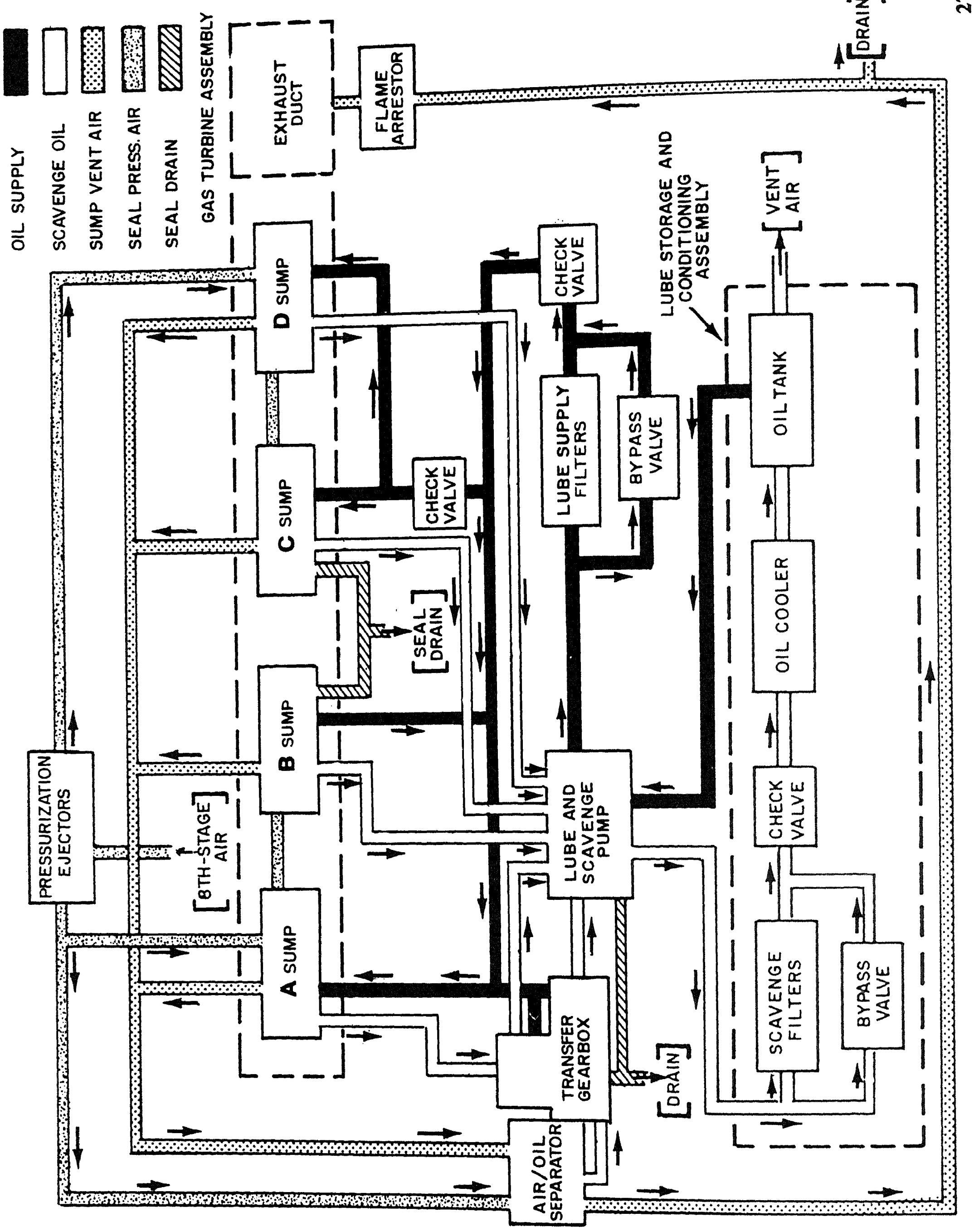

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Figure 5-27.—LM2500 lube oil system block diagram.

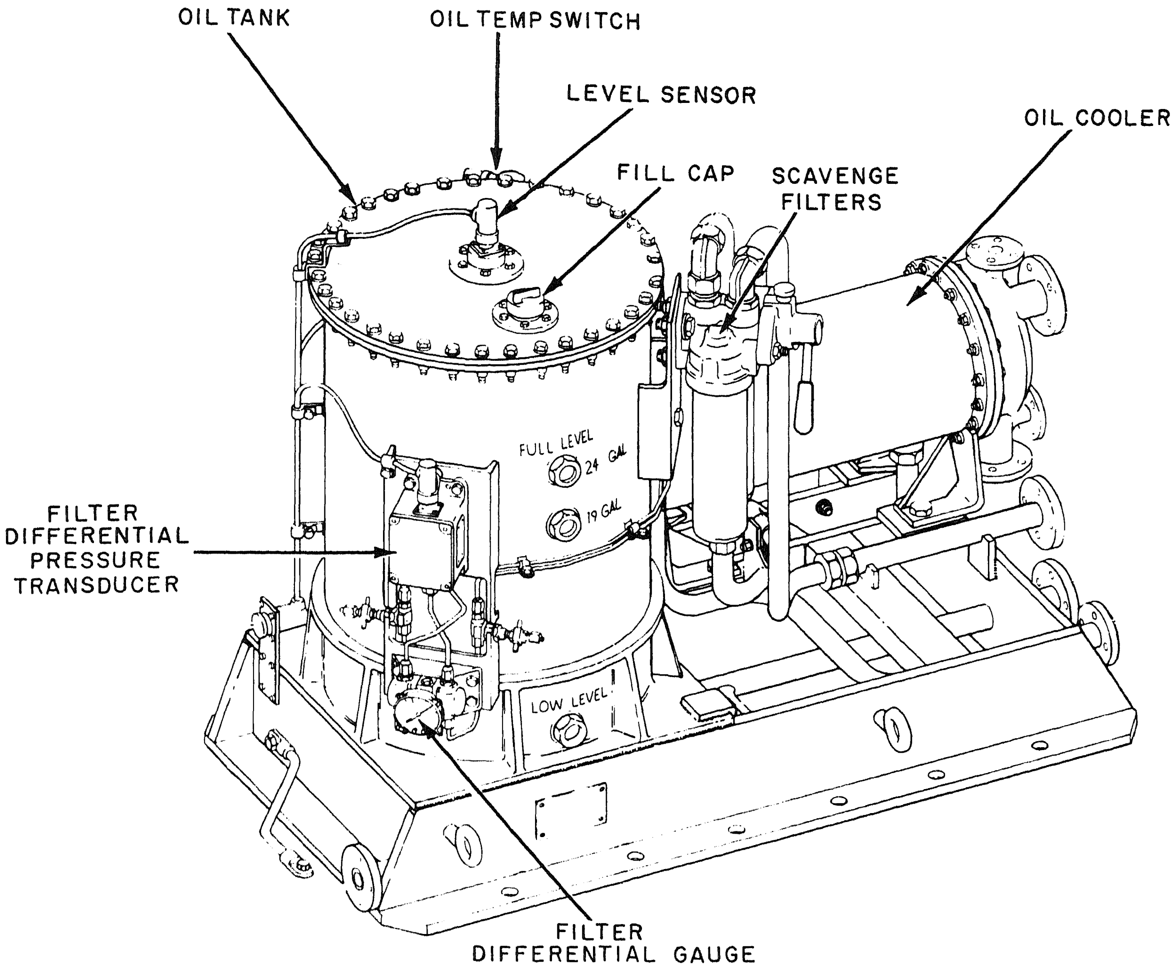

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Figure 5-28.—Lube oil storage and conditioning assembly.

seal (figure 5-29). This is to prevent oil leakage from the sumps. The cavity between the two seals is pressurized from aspirators (air ejectors), which are powered by eighth-stage air. The pressure in the pressurization cavity is always greater than the pressure inside the sump. Therefore, air flowing from the pressurization cavity, across the oil seal, prevents oil from leaking across the seal.

The scavenge oil is drawn in from the sumps and transfer gearbox by the five scavenge elements of the pump. It passes through the pump, through an outlet fitting on the enclosure base, and is returned to the LOSCA.

At the LOSCA the oil passes through the scavenge filters to the scavenge check valve. It then goes through the heat exchange. The heat exchange uses MRG (2190 TEP) lube oil to cool the MIL-L-23699. The cooled oil is then routed to the oil tank for storage and deaerating.

LUBE OIL SYSTEM COMPONENTS

In the following paragraphs we will describe the eight lube oil system components. They include the lube and scavenge pump, the lube supply filter and check valve, the C and D sump check valve, the scavenge oil filter and check valve, the heat exchanger, and the oil tank.

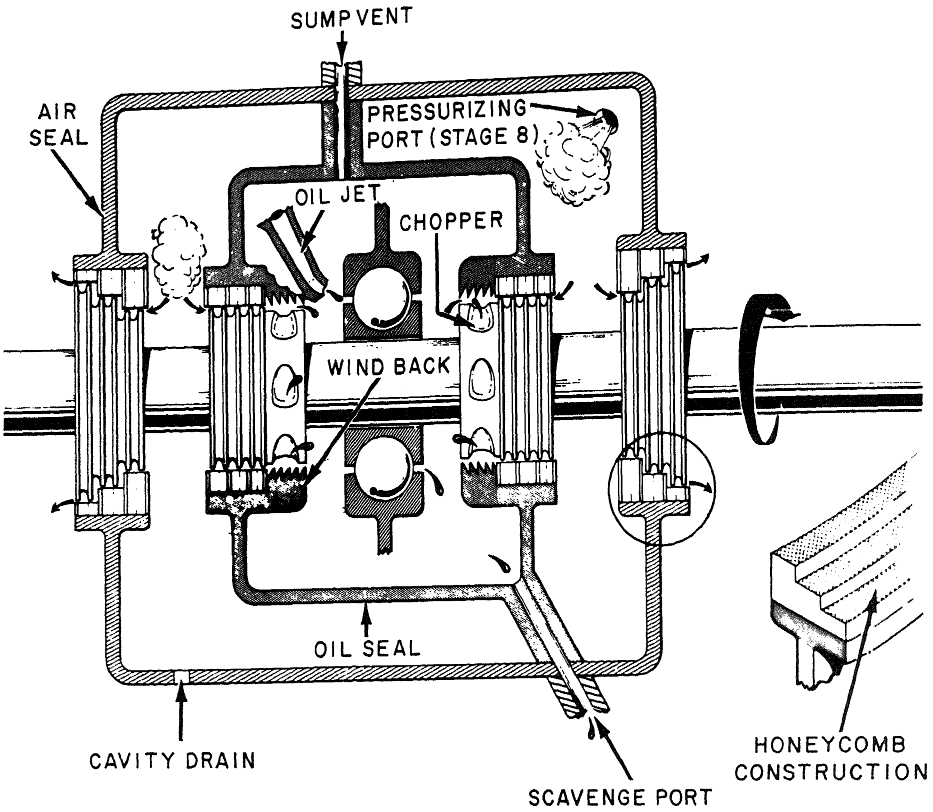

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Figure 5-29.—Bearing sump principles.

Lube and Scavenge Pump

The lube and scavenge pump (figure 5-30) is a six-element positive-displacement vane type of pump. One element is used for lube supply; five are used for lube scavenging. Within the pump are inlet screens, one for each element, and a lube supply pressure limiting valve. The outputs of the five scavenge elements are connected inside the pump and discharge through a common scavenge port.

Lube Supply Filter

The lube supply filter is a duplex type which allows for manual selection of either element. Filtration is 74 microns (nominal). A relief valve in the filter will open to allow oil to bypass a clogged filter. You select filters by raising a spring-loaded locking pin. Then move the selector handle until it is in front of the element not to be used. You then release the locking pin, making certain that the pin is engaged in the locking slot. A drain plug is located in the bottom of each filter bowl. It permits you to drain oil from the element before removal for cleaning.

Lube Supply Check Valve

The lube supply check valve is located on the downstream side of the supply filter. It prevents oil in the tank from draining into the sumps when the gas turbine is shut down. It will open and flow 20 gallons per minute (gpm) with a maximum of

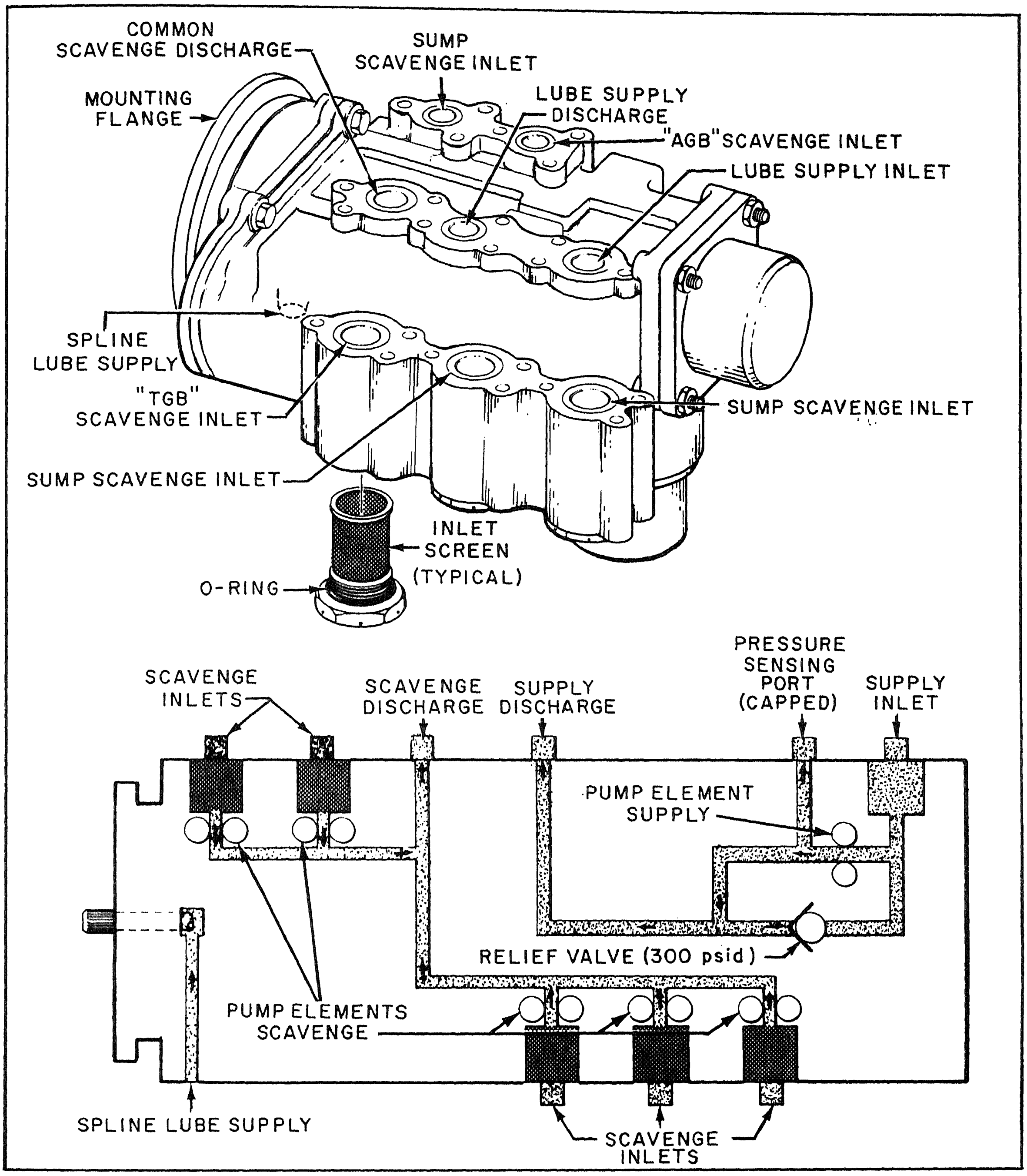

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Figure 5-30.—Lube and scavenge pump.

15 pounds per square inch differential (psid) pressure.

C and D Sump Check Valve

This check valve is located in the lube supply line to the C and D sumps. It isolates the C and D sumps from the GG lube oil system when an external lube supply and scavenge system is used for the PT. The C and D sump oil supply and scavenge lines have fittings to allow the use of an external lube system for the PT. During normal engine operation, lube oil is supplied to the C and D sumps from the lube pump. The check valve opens at 2 psid pressure.

Scavenge Oil Filter

The scavenge oil filter is a duplex type identical to the supply filter described earlier in this section. The only difference is that filtration of the scavenge oil filter is 46 microns (nominal).

Scavenge Oil Check Valve

The check valve is located between the scavenge filter and the heat exchanger. It prevents oil in the scavenge lines from draining back into the sumps and gearbox during engine shutdown. The valve will open and flow 20 gpm with a maximum differential pressure of 15 psid.

Heat Exchanger

The heat exchanger (oil cooler) is a shell-tube assembly. The coolant, MRG lube oil, passes from the MRG lube oil cooler through temperature control valves. It then flows through the inside of the tubes. The synthetic lube oil passes around the outside of the tubes. You remove the end domes for direct access to clean the inside of the coolant tubes.

Oil Tank

The oil tank (figure 5-28) has sight glasses for visual determination of oil level in the tank. An oil level switch monitors oil level from within the tank. It transmits a signal when the system level is too high or too low. The tank is considered full when it contains 24 gallons. Mounted on the tank are instrumentation valves, a filter differential pressure transducer, a filter differential pressure gauge, and an oil temperature sensor. Baffles, located in the bottom of the tank, minimize oil sloshing. Inside the tank at the scavenge inlet is a deaerator. It separates air from the scavenge oil and vents the air through the oil tank vent. A gravity fill port is located on the tank cap. A drain valve is located in the assembly base.

AIR INTAKE SYSTEM

The air intake system for the LM2500 provides the large quantity of air needed for engine operation. The design of the ducting varies with the classes of gas turbine ships. But they all provide the same functions. The intake system reduces the flow distortion, pressure drop, and salt ingestion. The intake system also provides duct silencing, a supply of cooling air, anti-icing protection, and a route for engine removal.

DD-963, DDG-993, AND CG-47 INLET DUCT SYSTEMS

The inlet duct systems for the DD-963, DDG-993, and CG-47 classes of ships are very similar. The only major difference is the sand separators used on the DDG-993 class. Since these occur on only four ships, we will not discuss them in this book.

Overall Flow Description

Refer to figure 5-31 while you are reading this section. It shows the intake duct system of the DD-963 and CG-47 classes of ships. Intake air enters the main duct through the moisture separator. This is located in the sides of the high hat inlet. The air flows down the main duct and passes through silencers located about midway down the duct. It then flows through a flexible coupling into the engine inlet plenum. Cooling air is taken off the main duct ahead of the silencers. It flows through the cooling duct, cooling duct silencers, and cooling air fan. It then enters the engine enclosure through a vent damper. The air circulates around the engine and exits the enclosure through the exhaust plenum.

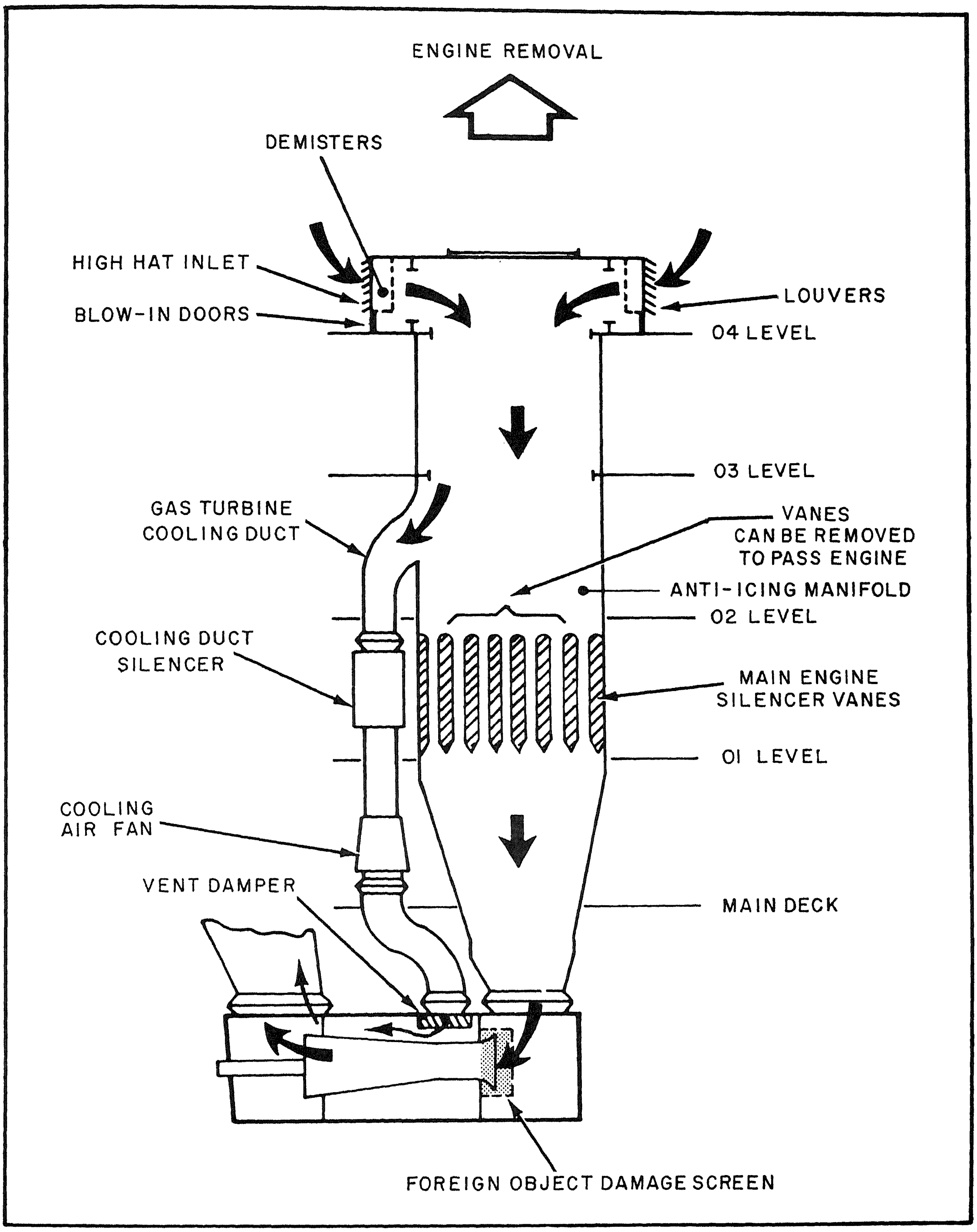

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Figure 5-31.—Intake duct system, DD-963, and CG-47 classes.

If the moisture separation system becomes blocked, the blow-in doors open. These are located below the inlet louvers. They automatically open to supply the engine with combustion and cooling air. In this mode of operation there is no demisting protection.

High Hat Assembly

The high hat assembly (figure 5-32) is located on the 04 level of the ship. It contains the moisture separation system and the blow-in doors.

MOISTURE SEPARATION SYSTEM.— The moisture separation system includes the inlet louvers and the demisters. The inlet louvers are arranged in sections. They are located in the sides of the high hat assembly. The design and arrangement of the louvers are such that they shed spray. The louvers are electrically heated to prevent icing. These heaters are strip type and are located on the back of the louver surface. The heaters are controlled from the engine control consoles. The demisters are two-stage mesh-pad type mounted vertically behind the louvers. Water, separated from the inlet air as it passes through the demisters, is collected in scuppers and is drained overboard. Demister performance is shown below:

Particle Size	Removal Efficiency
5 microns and larger	90%
1.7 microns to 5 microns	70%

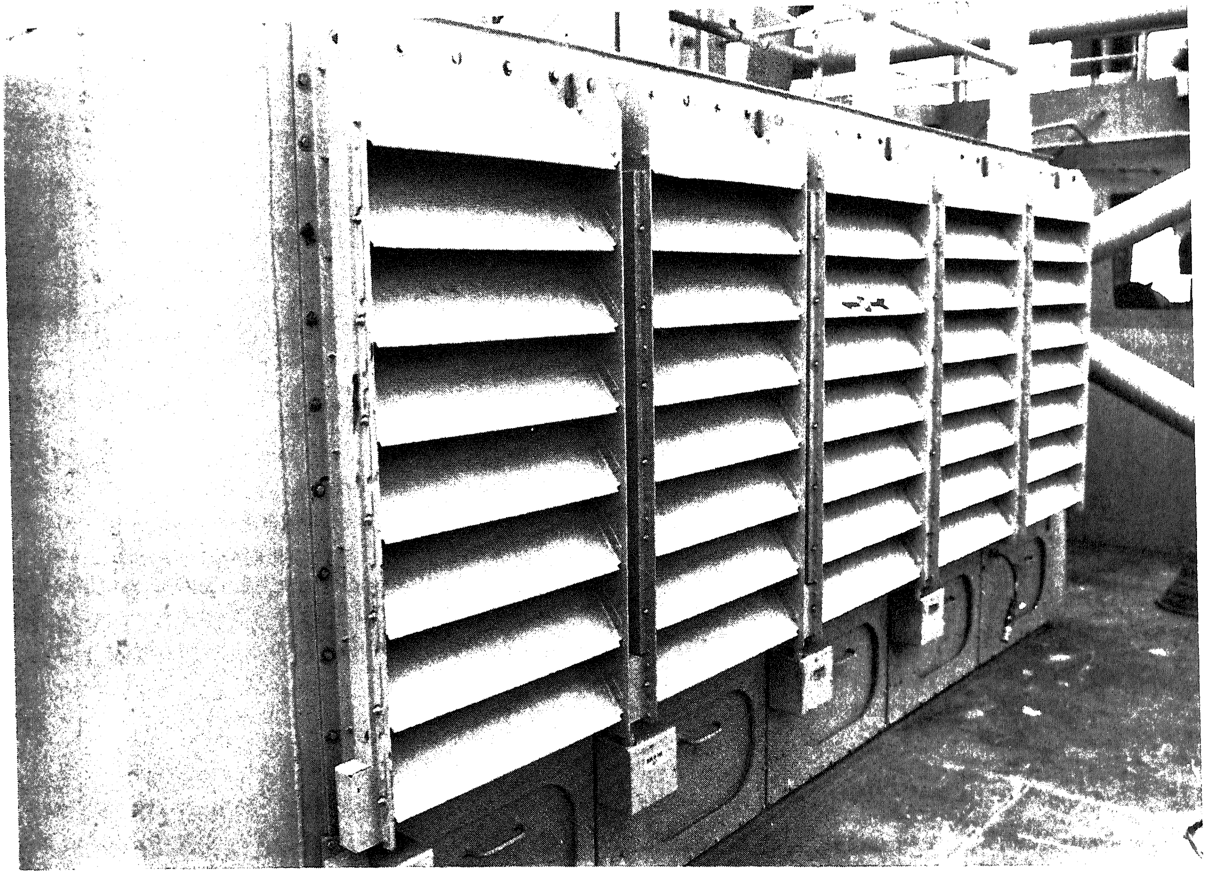

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Figure 5-32.—DD-963 type of blow-in doors and louvers.

BLOW-IN DOORS.—The blow-in doors are located just below the inlet louvers. They are designed to open by solenoid-operated latch mechanisms. They open if the inlet airflow becomes too restricted for normal engine operation. Their function is to bypass the moisture separation system. They provide an unrestricted inlet airflow to the engines if the moisture separation system becomes blocked.

A controller is located in each engine room to provide for manual or automatic operation. This is done by a selector switch and a pushbutton on the controller door. On the CG-47 class this controller is in the helo hangar. The pushbutton on the CG-47 class is located on the high hat assembly. In manual operation, you can only open the doors by depressing the pushbutton. In automatic operation, you can only open the doors by operation of a pressure switch. The switch operates on low duct pressure. This pressure switch also provides a DUCT PRESSURE LOW signal to propulsion auxiliary machinery control equipment (PAMCE) and propulsion local control equipment (PLOE). The pressure switch operates when duct pressure falls below 8 inches of water. Once tripped, you must manually reset the doors closed.

Ducting

The ducting allows the air to travel from the high hat assembly to the inlet of the compressor. The components of the ducting include the silencers, the anti-icing piping, the cooling air duct, and the engine removal system.

SILENCERS.—The main engine intake duct silencers are located about halfway down the duct. The silencers are vertical vane assemblies consisting of sound-deadening material. It is encased in perforated stainless steel sheet. The vanes are arranged in modules which are removable. This permits removal of the GTEs through the intake duct.

ANTI-ICING PIPING.—This system prevents the formation of ice in the intake duct. High-temperature bleed air from the GTEs is piped to a manifold. This manifold is located inside the duct between the cooling air extraction port and the silencers. From the manifold the bleed air is discharged into the inlet airstream. The air is mixed with the inlet air, raising the temperature enough to prevent the formation of ice. When enabled from PLOE or PAMCE, an electromechanical control system regulates bleed air flow. This controls the inlet air temperature to 38 °F nominal, enough to prevent the formation of ice. It also melts away built-up ice or snow, regardless of dew point. A temperature sensor in the stack provides an ANTI-ICING INSUFFICIENT signal. This tells when the anti-icing system has been enabled and the temperature drops below 36 degrees.

COOLING AIR DUCT.—Main engine cooling air is extracted from the main intake duct. It is taken at a point between the blow-in doors and the main duct silencers. It is then ducted to the engine enclosure. The cooling air duct contains a silencer and a cooling air fan. The cooling system will be discussed in more depth later in this chapter.

ENGINE REMOVAL SYSTEM.—It may become necessary to remove a propulsion engine from the ship for maintenance/overhaul. If so, the engine is removed through the intake duct. At the time of engine removal, a set of channel-shaped maintenance rails is installed in the engine enclosure. These are put adjacent to each side of the engine. A set of rollers, which fit into the rails, is attached to each side of the engine. The removable maintenance rails extend into the enclosure inlet plenum. They then turn 90 degrees, from horizontal to vertical attitude. They mate with permanently installed rails that extend up the intake duct. In the inlet plenum, three sets of maintenance rails interface with three sets of permanently installed rails in the ship's intake duct. The permanently installed rails extend through the high hat section. These serve to guide the engine as it is lifted vertically from the ship.

Removal of the engine is accomplished in two operations. The GG is separated from the PT while still in the enclosure. The GG is then removed from the ship first, followed by removal of the PT.

FFG-7 INLET DUCT SYSTEM

The gas turbine uptake and intake system consists of three separate ducting systems (figure 5-33). They are for combustion air, cooling air, and exhaust gas elimination. Atmospheric air for the combustion and cooling air ducting normally enters through the intake plenums (figure 5-34). These are located on each side of the ship's structure. The air is then carried through ducting to the GTMs in the engine room below. Ducting connections to the GTMs are made via expansion joints on top of each GTM. The combustion air intake ducts also provide the access for removal and replacement of the engine GG and PT sections.

Besides the ducting, the gas turbine uptake and intake system includes moisture separator assemblies, emergency inlet doors, and cooling air fans. Also included are cooling air bypass dampers and provisions for anti-icing upstream and downstream of the moisture separators.

Moisture Separators

The moisture separators are of knit wire mesh construction mounted in a supporting frame. They remove moisture droplets containing sea salt. They also prevent other foreign objects from entering the intake and cooling air ducts. In operation, the moisture droplets adhere to the wire mesh while the air passes through. The moisture droplets coalesce into larger drops and fall free of the airstream. They then drain into troughs which are piped to the plumbing drains system. There are eight panels of moisture separators for each combustion air intake duct. There are four panels for each cooling air duct.

Emergency Inlet Doors

Emergency inlet doors are provided in the combustion air and cooling air ducts to each engine. One emergency inlet door is located between the uptake space and each combustion and cooling air duct. If the moisture separators start to ice or are partially blocked for any reason, the emergency inlet doors will open. These open automatically to provide inlet air from the uptake

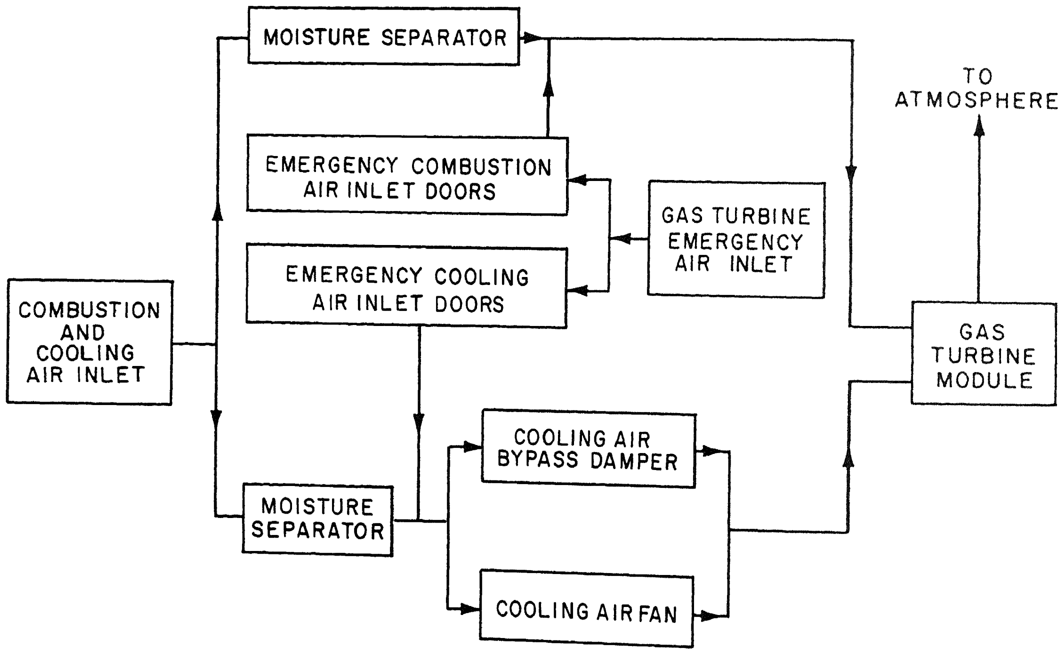

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Figure 5-33.—Block diagram of FFG-7 air intake system.

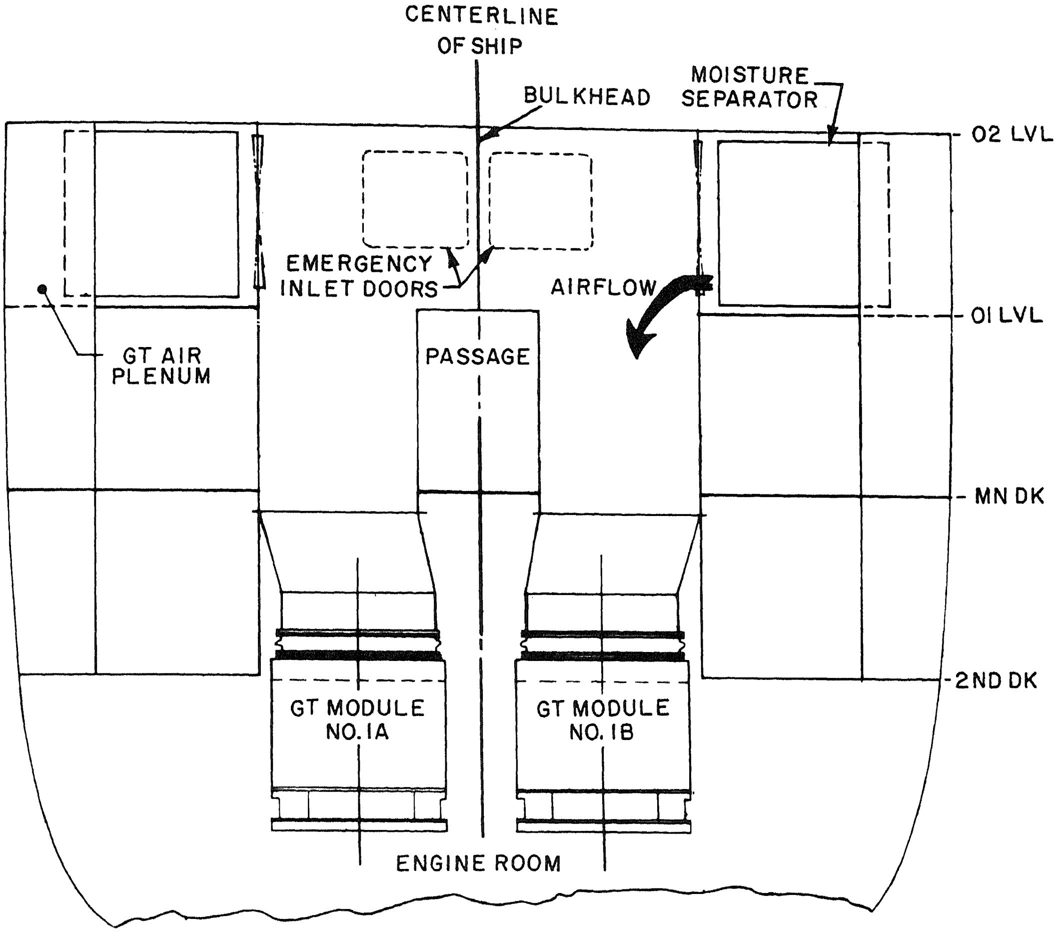

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Figure 5-34.—FFG-7 class air intake system.

space and permit continued limited power engine operation. The doors are pneumatically actuated and automatically controlled by differential pressure switches. Each combustion air emergency inlet door opens automatically at a differential pressure of 9.0 inches of water. The cooling air emergency inlet doors open automatically at 3.0 inches of water differential pressure. You can actuate each door manually using the air solenoid override at the door control panel. You can also open them manually using a wrench at the door assembly.

Anti-Icing System

An anti-icing system uses bleed air from the GT. It is used to prevent the formation of ice in the intake system. Anti-icing nozzles are located upstream and downstream of the moisture separators.

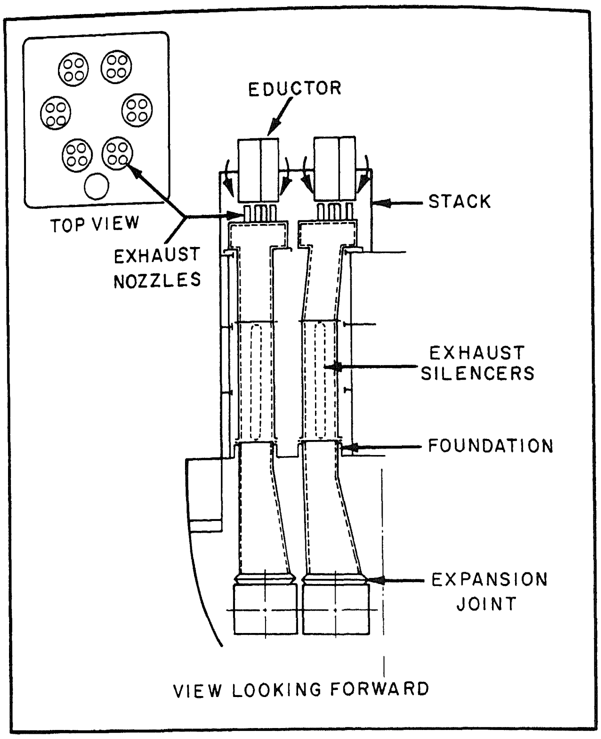
Bleed air from each GG is piped to its associated intake system for anti-icing purposes. The piping to each intake system contains a 250/38 psig regulating valve to reduce the bleed air pressure. The bleed air supplied to the intake system provides anti-icing air for the moisture separators, the GG bellmouth, and the enclosure cooling fan. Bleed air also supplies the cooling air bypass damper and the enclosure cooling air damper.

The anti-icing pressure regulating valve is actuated from either the propulsion control

console (PCC) or the LOP. Valve status indication is provided at both control stations.

Intake Monitoring and Control

Outside air temperature is sensed by an RTD. It is mounted in each intake plenum upstream of the moisture separators. The temperature is displayed on the PCC demand display and on an edgewise meter on the LOP. The temperature signal is used by the propulsion control system (PCS) for gas turbine enclosure ventilation damper logic. It is also used for automatic GT power correction when operating in programmed control. A differential pressure sensor measures the pressure difference between the intake duct and outside atmospheric pressure. If the differential pressure exceeds 7.5 inches of water, the combustion air intake LP alarm is activated on the PCC in the central control station (CCS). This parameter can also be demand displayed on the PCC.



286.25.1
Figure 5-35.—DD-963/DDG-993 exhaust duct system.

EXHAUST SYSTEM

The gas turbine exhaust system expels the exhaust by preventing reingestion of the exhaust gases. This system also minimizes the sound and the heat sensing of the ship by hostile vessels and aircraft. Reingestion of the exhaust gases is prevented by having the exhaust stack higher than the air inlet ducts. Sound level is reduced by exhaust duct wall insulation. On some ship classes a silencer is installed to assist in noise reduction. Exhaust heat is reduced by combining the module cooling air with the hot gases. Exhaust gas temperature may be further reduced by an IR suppression system.

DD-963/DDG-993 CLASS EXHAUST SYSTEM

These ship classes employ silencers and a saltwater-cooled IR suppression system. A DD-963/DDG-993 type of exhaust system is shown on figure 5-35.

Silencers

A single vane type of silencer is located in the center of the duct. It has sound-deadening material encased in perforated stainless steel sheet. This and duct wall insulation reduce the sound level enough to meet the airborne noise requirements.

Eductors

The exhaust eductors are located at the top of each propulsion engine exhaust duct. They mix outside air and the IR suppression spray with the turbine exhaust gases before releasing them into the atmosphere (figure 5-36). The eductor is basically a mixing tube which protrudes from the exhaust stack top. It is positioned so the gas flow from the exhaust nozzles will draw outside air into the exhaust stream. It also draws IR suppression spray into the exhaust as it enters the mixing tube.

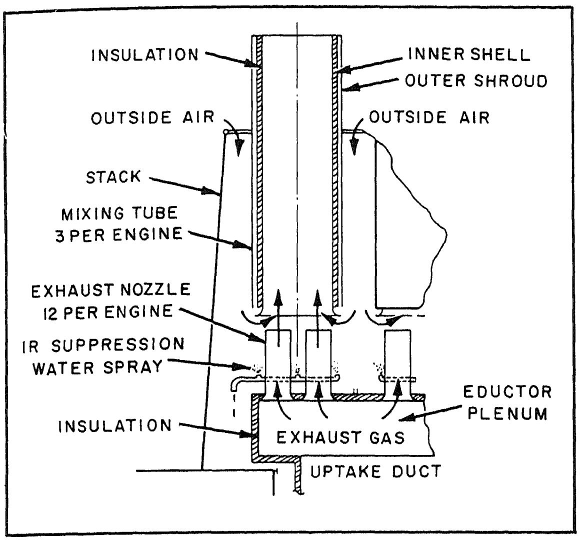


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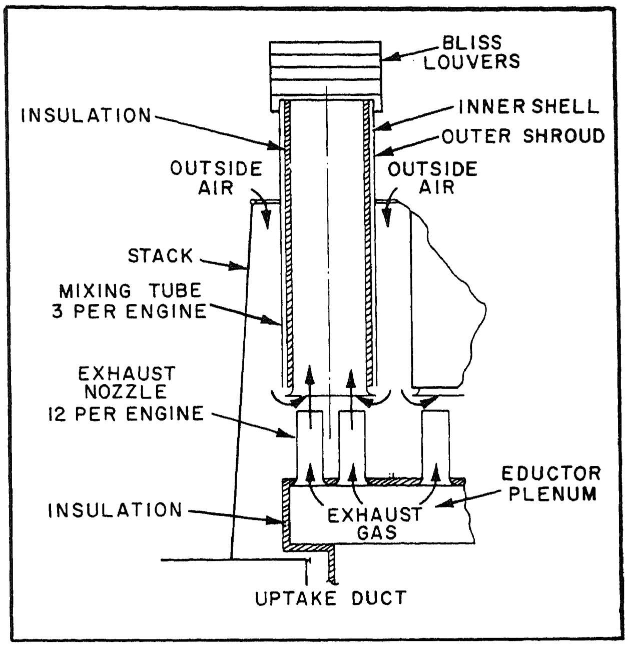
Figure 5-36.—DD-963/DDG-993 exhaust eductor.



286.26.2

Figure 5-37.—CG-47 class exhaust eductor.

Infrared Suppression

The propulsion engine IR suppression system reduces exhaust gas temperature. It does this by injecting a seawater spray into the exhaust stream before it leaves the eductors. Below each eductor mixing tube is a water spray ring manifold. This encircles the associated four exhaust nozzles (figure 5-36). It gives a total of six spray manifolds for each of the two main engine exhaust stacks. Seawater is pumped up to the eductors from the firemain water system. It is then sprayed vertically upward from the spray manifolds. The spray is drawn into the eductor tube by the exhaust streams. The fresh airflow mixes with the gases before leaving the stacks.

CG-47 CLASS EXHAUST SYSTEM

The CG-47 exhaust system is similar to the DD-963/DDG-993 class with only one major exception. On the CG-47 class the IR suppression system has been replaced with a boundary layer IR suppression system (BLISS) (figure 5-37). This system is comprised of a series of eductors at the top of each exhaust stack. BLISS is in continuous operation.

FFG-7 CLASS EXHAUST SYSTEM

The uptake system (figure 5-38) conducts the GT combustion exhaust gases and the enclosure exhaust air to the atmosphere. The exhaust trunk extends from the exhaust expansion joint at the enclosure, up through the ship. It terminates in the atmosphere above the top of the stack. The enclosure cooling air exhaust is drawn into the exhaust trunk through the action of an eductor at the top of the enclosure. An RTD is mounted in the exhaust trunk. It provides a signal to the propulsion control system for the demand display at the PCC of the exhaust temperature.

MODULE COOLING SYSTEM

Navy gas turbines are not rated for operation in high ambient temperatures above 130°F. A module cooling system must be used to prevent operation of the engine in temperatures greater than 130°F.

The LM2500 GTM uses a combination of fan-forced ventilating air and exhaust gas eduction to

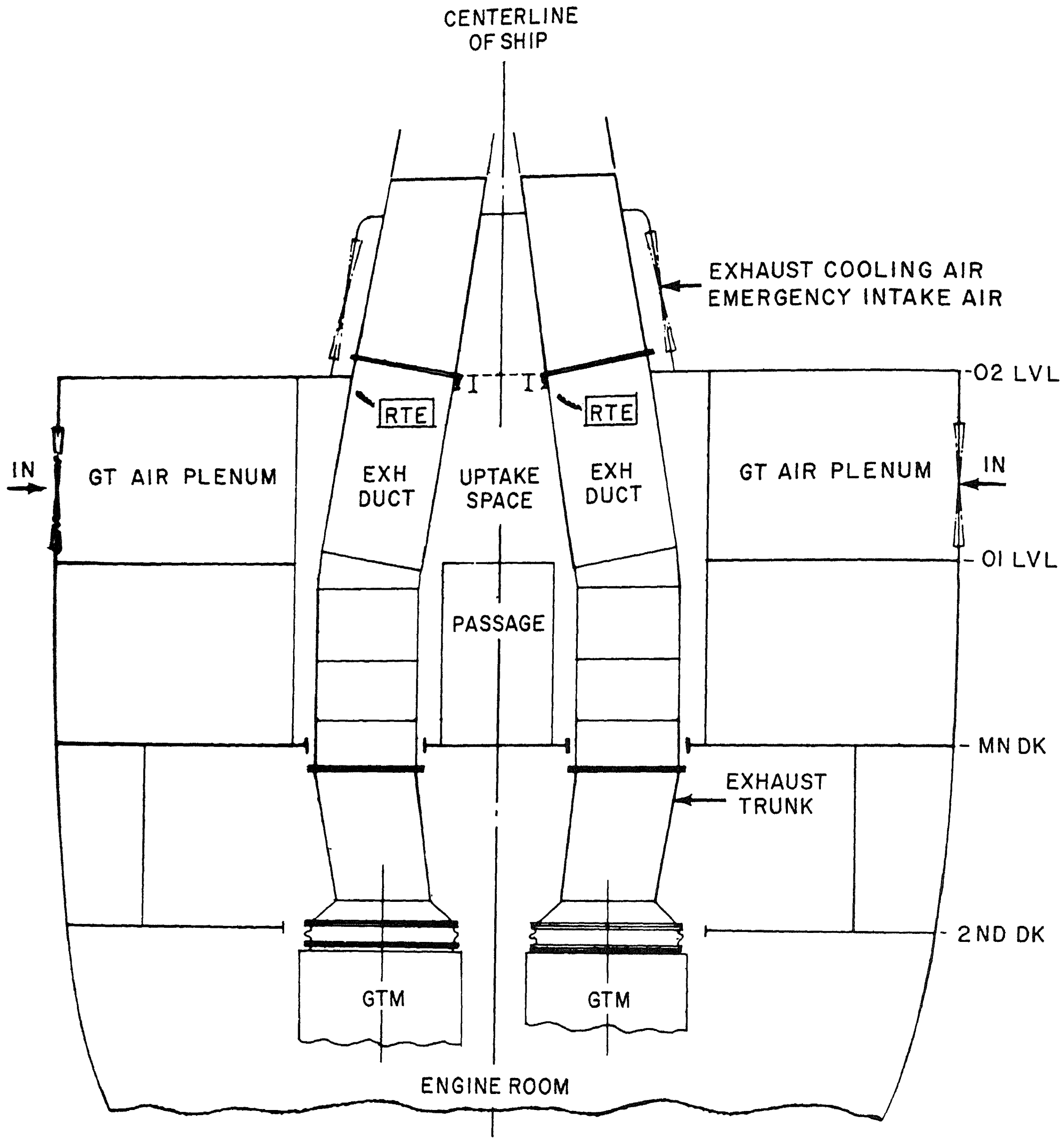


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Figure 5-38.—FFG-7 class exhaust system.

cool the GTM (figure 5-39). Cooling air is taken into the cooling duct and pressurized by the fan. It is then discharged at the ventilation damper on the top of the module. Once the air enters the module, a natural swirling effect takes place around the engine. The cooling air moves to the back of the module where it is removed by the exhaust eductor. Although the cooling systems of the different classes perform the same function, they are constructed differently. The following sections of this chapter describe these differences.

DD-963, DDG-993, AND CG-47 CLASS COOLING SYSTEM

Main engine cooling air is extracted from the main intake duct at a point between the blow-in doors and the main duct silencers. It is then

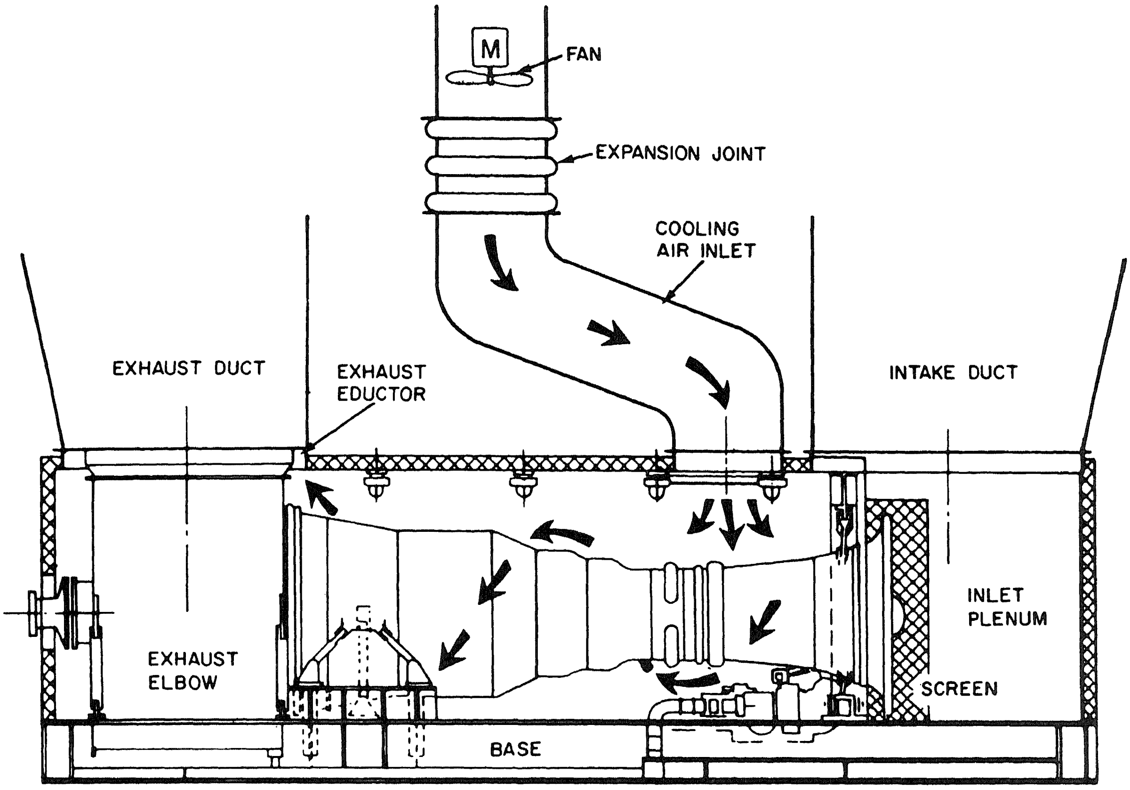

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Figure 5-39.—Gas turbine module cooling.

ducted to the engine enclosure. The cooling air duct contains a silencer and a cooling air fan. The silencer consists of a double-walled cylinder. The outer wall is solid sheet and the inner wall is perforated sheet. The space between is filled with sound-deadening material. Suspended in the center of the cylinder is a torpedo-shaped baffle. It is made of perforated stainless steel sheet filled with sound-deadening material. The silencer forms a section of the cooling air duct. The cooling air fan is located in the duct between the engine enclosure and the silencer. The fan is rated at 80 horsepower and flows air at 17,000 cubic feet per minute (ft^3/min).

From the cooling fan, the air is ducted to the engine enclosure. It enters the enclosure through a ceiling-mounted vent damper. Then it circulates around the engine. The air exits the enclosure through the exhaust plenum. The cooling is activated either manually or automatically from PLOE or PAMCE and must be running for engine operation. The vent dampers are electropneumatically operated. They use air from the ship's service air system (SSAS). The vent dampers are operable either automatically or manually from PLOE or PAMCE.

FFG-7 CLASS COOLING SYSTEM

The cooling air ducts to each engine are made up of two parallel sections (figure 5-40). One section contains a cooling air fan and the other a cooling air bypass damper. The two sections join together before connecting to the GTM. At low engine power the cooling air fan in one leg supplies cooling air to the GTM. This acts to close the bypass damper in the other leg. As the engine power level passes 3,000 shaft horsepower (SHP), the engine exhaust eductor creates enough draft for the bypass damper to open. Both parallel legs

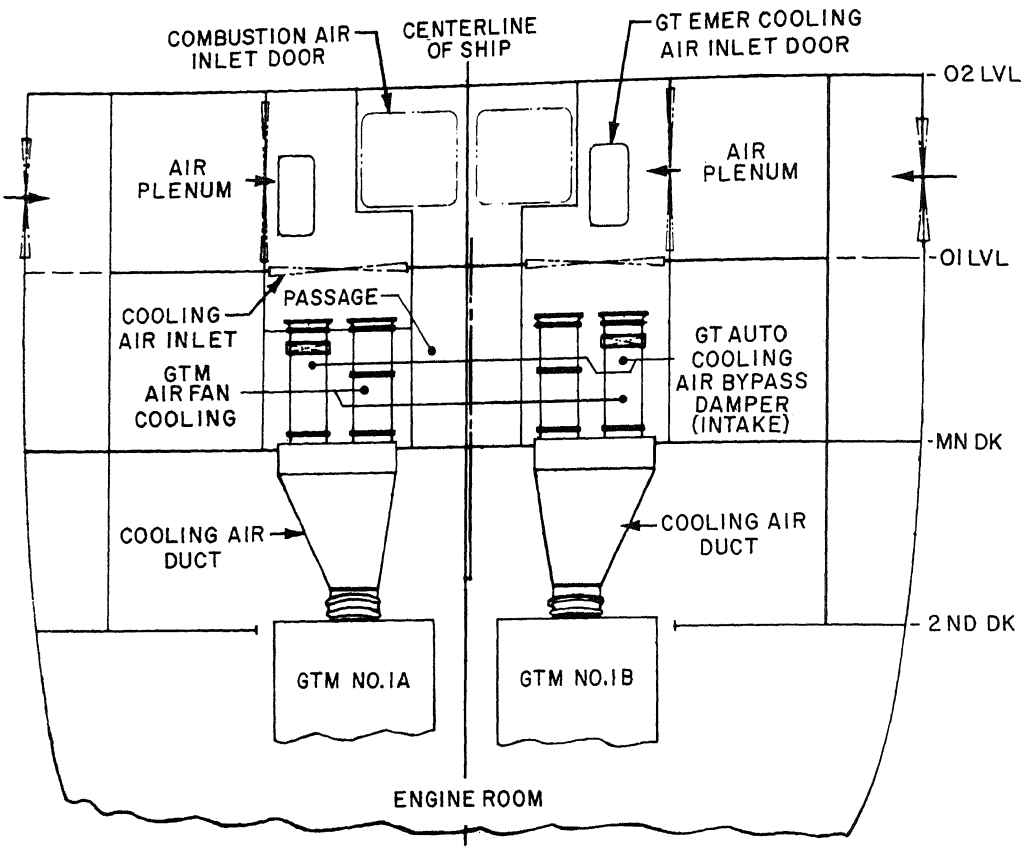

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Figure 5-40.—FFG-7 class cooling air system.

then permit cooling air to enter the GTM. The cooling air fan is shut off automatically at an engine power level of 3,000 SHP by the PCS.

The PCS provides the control and status indications for the cooling air fans at the PCC and the LOP. Both locations have controls for manually starting the fans. They also have automatic control of the fans after the GTs have been started. The fan local motor controller provides the only controls for stopping the fan in the manual mode. The cooling air bypass dampers have position switches that show the status of the bypass damper at the PCC.

STARTING AIR SYSTEM

The starting air system provides compressed air to rotate the engine starter through the accessory drive. The starter rotates the GG for starting, motoring, and water washing. The system uses either engine bleed air or HP air on the DD-963, DDG-993, and CG-47 classes. The FFG-7 class uses either engine bleed air or air from diesel driven start air compressors (SACs).

The start system (figure 5-41) has a pneumatic turbine starter and a starter valve. The starter is mounted on the aft side of the transfer (accessory) gearbox. The starter valve is line-mounted behind the starter. The starter drives the GG through the

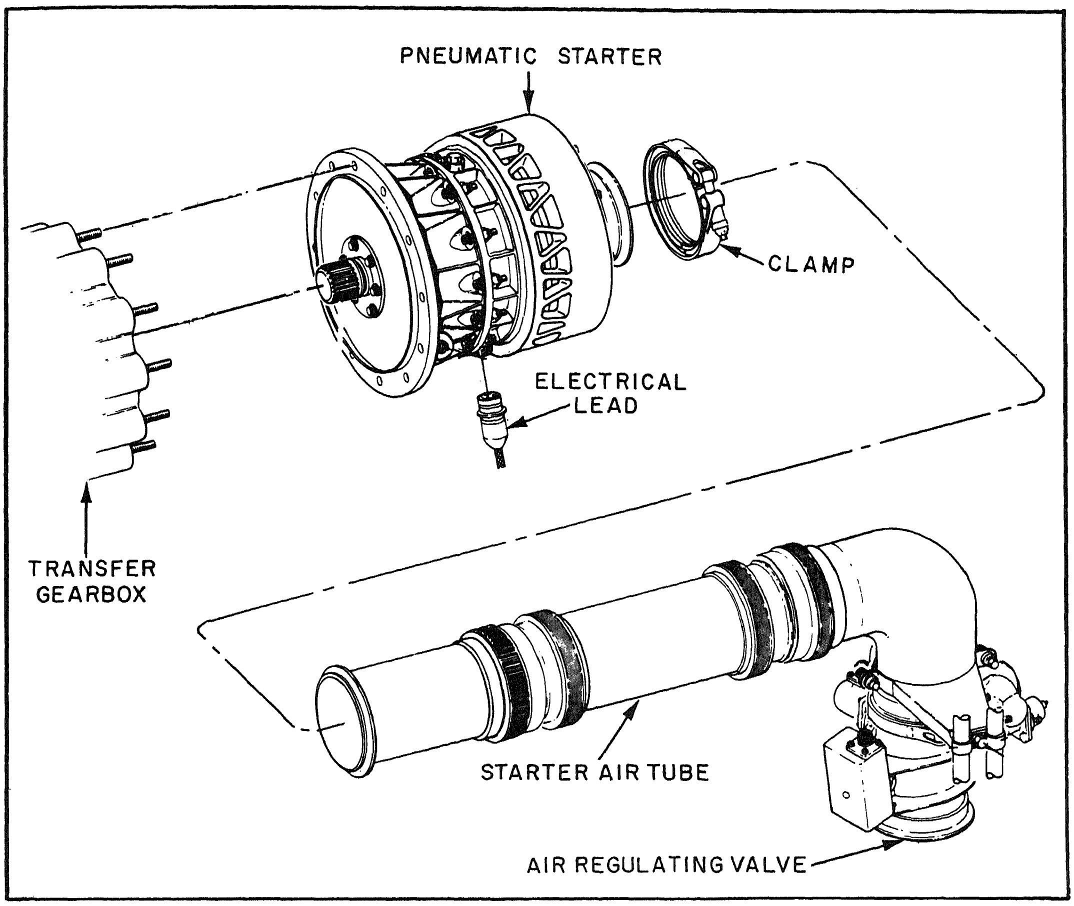

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Figure 5-41.—LM2500 air starting system.

gearbox during the start cycle. It drives it until the GG reaches or exceeds self-sustaining speed.

STARTER

The starter has an inlet assembly, a turbine assembly, and reduction gearing. It also includes a cutout switch, an overrunning clutch, and a splined output shaft. The turbine is a single-stage, axial flow type. The reduction gearing is a compound planetary system with a rotating ring gear. The overrunning clutch is a pawl and ratchet type. This provides positive engagement during starting and overrunning when driven by the GG. The cutout switch is normally closed. It is actuated by a centrifugal governor which trips open the switch. This also illuminates a STARTER CUTOUT indicator light at the propulsion consoles. The output shaft has a shear section to prevent overtorque damage. The starter operating air pressure is 35 to 41 psig for starting and 21 ± 1 psig for water washing. Air to the starter is piped from the starter air valve. The starter exhausts directly into the module enclosure.

STARTER VALVE

The starter valve is a normally closed pneumatic regulator and shutoff valve. It has a bleed-on regulator, a solenoid switcher, and a pneumatic switcher. It also incorporates a check valve, an actuator, and a butterfly valve. Air from the ship's start air system is supplied through an inlet fitting on the enclosure base to the starter

valve at 0 to 75 psig. When 28 volt d.c. power is supplied to the solenoid from the FSEE, the valve opens. It regulates discharge air pressure (to the starter) at 35 to 41 psig at a flow rate of 0 to 3.5 lb/sec.

Regulation is accomplished by the balance between the pneumatic actuator and a torsion spring on the butterfly. When the 28 volt d.c. signal is removed, the butterfly is closed by the pneumatic actuator and the torsion spring. Valve position is displayed by a mechanical position indicator at the valve. The valve position switch provides a valve position signal to the propulsion console.

LM2500 MODULE

The base/enclosure assembly has an enclosure on a shock-mounted base. It is about 26 feet long, 8 feet high, and 9 feet wide. The base/enclosure assembly is maintained in the installed position. That is, it is installed as a permanent part of the ship. This is opposed to the GT assembly which can be removed for major repair, overhaul, or replacement. Access for routine maintenance is provided by two entrances. Removable side panels are provided adjacent to one of the doors.

BASE

The base has a fabricated steel frame. It contains suitable mounts and links to secure the GT. Thirty-two shock mounts under the base secure the entire base/enclosure assembly to the ship's foundation. The shock mounts have two stacks of spring washers aligned above and attached to a resilient neoprene shock mount. They weaken shock loads by absorbing most of the abrupt up and down movements of the ship's foundation. The base also provides fittings for connection of electrical, air, CO_2, and liquid services (figure 5-42).

ENCLOSURE

The enclosure provides thermal and acoustical insulation. It also provides inlet and exhaust ducting, and a controlled environment for the GT. Flexible couplings are provided at the air inlet and exhaust ducts. This allows a flow path/interface between the enclosure and the ship's ducting. The right and left propulsion GT modules are functionally identical. They differ physically on the DD-963, DDG-993, and CG-47 classes only in the layout of the base/enclosure assemblies. The difference relates to access into the enclosure. Basically, entry to the left enclosure is through an access door on the left side of the enclosure. There is also an access hatch on the right side of the top panel. Entry to the right enclosure is through an access door on the right panel of the enclosure. The access hatch is on the left side of the top panel.

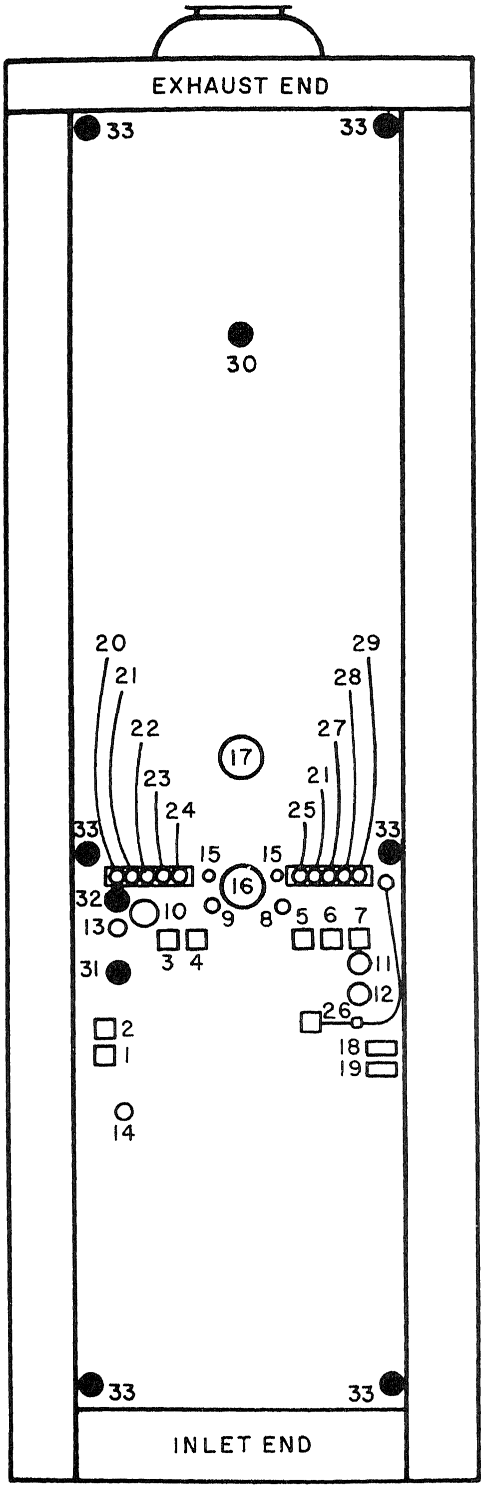
FIRE CONTAINMENT SYSTEM

All LM2500 modules have some method for detecting and extinguishing a fire in the enclosure. The sensors used to detect a fire are identical on all classes. These sensors are described in detail in chapter 3. The use of these sensors and the fire extinguishing systems varies with ship classes.

Fire Detection, Alarm, and Extinguishing—DD-963, DDG-993, and CG-47

The fire detection system has three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system has a manual fire alarm pushbutton besides the electrical signal generated by either the temperature switch or the flame detector signal conditioner. The extinguishing system has two carbon dioxide (CO_2) discharge nozzles. It also has an extinguish release inhibit switch and a CO_2 release switch.

The UV flame detectors sense the presence of fire in the enclosure. They generate an electrical signal which is transmitted to the signal conditioner. The conditioner provides a signal to the ship's fire extinguishing system. The temperature switches are mounted on the interior ceiling of the enclosure. Temperature above a preset value causes switch contacts to close. This provides a signal to the ship's fire extinguishing system.



1. P_{T2} TRANSDUCER
2. P_{S3} TRANSDUCER
3. FUEL MANIFOLD PRESSURE TRANSDUCER
4. FUEL PUMP FILTER ΔP TRANSDUCER
5. LUBE OIL SUPPLY FILTER ΔP TRANSDUCER
6. LUBE OIL SUPPLY PRESSURE TRANSDUCER
7. $P_{T5.4}$ TRANSDUCER
8. E8-ICE DETECTOR AND FLAME DETECTOR SIGNAL CONDITIONER
9. E10-PRESSURE TRANSDUCERS (P_{S3}, P_{T2}, FUEL MANIFOLD PRESSURE, FUEL FILTER ΔP, LUBE SUPPLY FILTER ΔP, LUBE OIL, $P_{T5.4}$)
10. FUEL OIL INLET
11. LUBE OIL INLET
12. LUBE OIL SCAVENGE OUTLET
13. VENT DAMPER ACTUATOR AIR INLET
14. WATER WASH INLET
15. CO_2 INLETS (PRIMARY & SECONDARY)
16. STARTER AIR INLET
17. BLEED AIR OUTLET
18. FLAME DETECTOR SIGNAL CONDITIONER
19. ICE DETECTOR SIGNAL CONDITIONER
20. E11-PLA ACTUATOR MOTOR, RATE TACH, POSITION POT
21. BLANK
22. E6-VALVE CONTROLS (VENT DAMPER, STARTER REGULATOR SHUT-OFF, BLEED AIR, FUEL PURGE) AND, VENT DAMPER OPEN/CLOSE LIMIT SWITCH
23. E5-FUEL/ENCLOSURE HEATER POWER
24. E7-IGNITION, ENCLOSURE LIGHTS
25. E9-RTDS (T_2, FUEL INLET, COOLING AIR OUT)
26. E4-$T_{5.4}$ SIGNAL CONDITIONER
27. E3-POWER TURBINE SPEED PICKUPS NO.1 AND NO.2
28. E2-VIB TRANSDUCERS (GAS GENERATOR, POWER TURBINE) AND RTD'S (A,B,C,D SUMPS AND ACCESSORY G/B SCAVENGE OIL TEMPERATURE)
29. E1-FUEL S/D VALVES NO.1 AND NO.2 AND STARTER O/S SWITCH, GG SPEED PICKUP
30. EXHAUST DUCT DRAIN
31. FUEL SYSTEM DRAIN
32. FUEL MANIFOLD SHROUD DRAIN
33. MODULE FLOOR DRAINS

NOTE: PREFIX E DENOTES ELECTRICAL CONNECTOR

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Figure 5-42.—Base penetration plate connections (bottom view).

The CO_2 release switch (figure 5-43) is mounted to the outside of the enclosure, next to the side access door. When manually activated, the CO_2 fire extinguishing agent is discharged into the enclosure.

The CO_2 discharge nozzles are located inside the enclosure. They are mounted on the crossbeam under the compressor front frame. There are two nozzles, one for initial discharge and one for extended discharge. The fire extinguish release inhibit switch is mounted above the fire alarm pushbutton. When in the INACTIVE position, this switch prevents discharge of the CO_2 extinguishing agent.

Fire is sensed by the flame detectors or temperature switches (figure 5-44). It may also be noted by a crew member who operates the manual CO_2 release switch. When this occurs, contacts

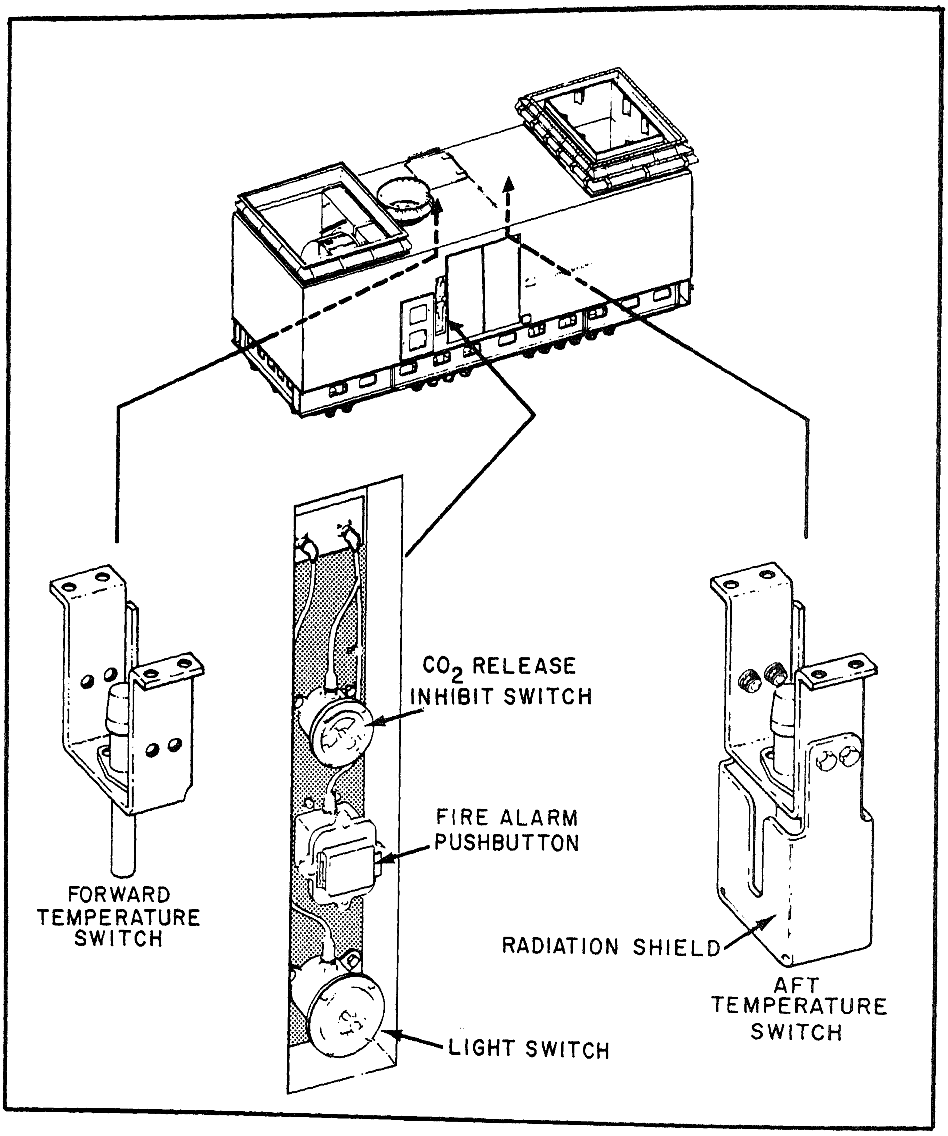

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Figure 5-43.—Fire system temperature sensors and manual switches.

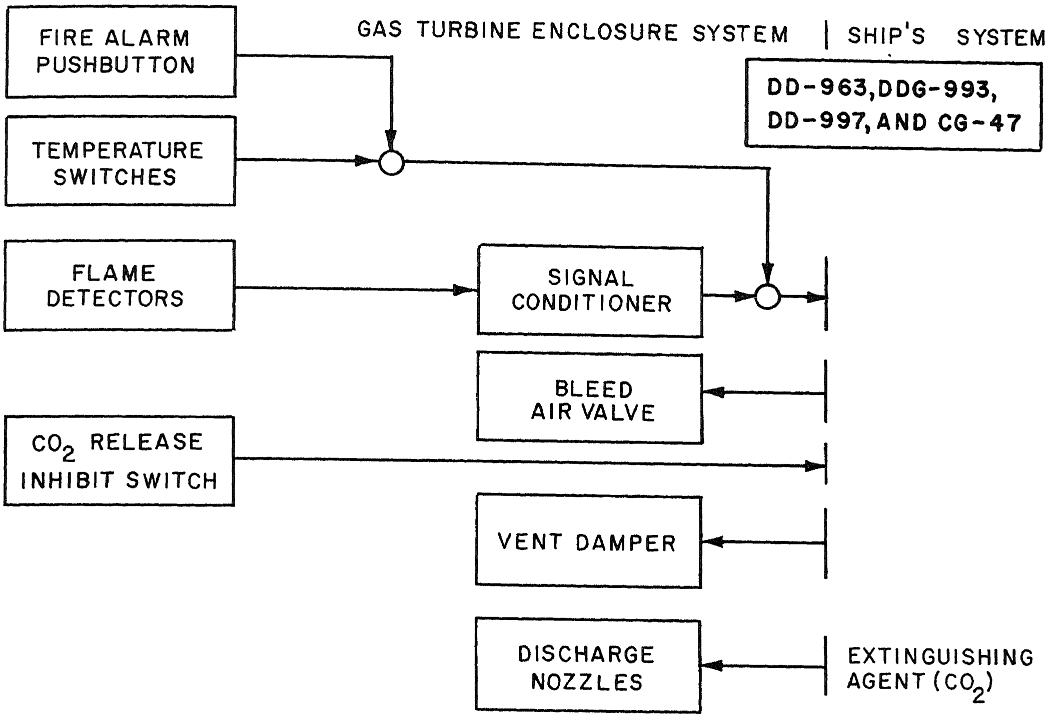

Figure 5-44.—Fire system block diagram.

close to activate the fire extinguishing system. The following concurrent actions occur:

1. The GT fuel shutdown valves close, shutting down the GT.
2. The fuel supply to the GTM is shut off in the ship's service system.
3. The bleed air valve is closed.
4. The secondary cooling air fan is shut down.
5. The secondary air vent damper is closed.
6. The fire alarm signal sounds.
7. The enclosure lights flash.
8. After a delay of 20 seconds, the initial CO_2 discharge occurs. You can prevent CO_2 discharge by positioning the release inhibit switch to the INACTIVE position during the time delay. The initial discharge delivers 150 pounds of CO_2 at a rate of 50 lb/min. If required, the extended CO_2 discharge is manually activated. The extended discharge delivers 200 pounds of CO_2 at the rate of 10 lb/min.

Fire Detection, Alarm, and Extinguishing—FFG-7

Like the other ship classes discussed above, the fire detection system of the FFG-7 class has three flame detectors, a flame detector signal conditioner, and two temperature switches. The alarm system consists of a fire alarm pushbutton. The extinguishing system consists of a single Halon discharge nozzle, connecting tubing, and an extinguish release inhibit switch.

The UV flame detectors of the FFG-7 class are identical to the type on the DD-963, but provide only an alarm. The RTD fire sensor will also sound that same alarm indicating a fire is present.

The fire alarm pushbutton is mounted on the outside of the enclosure, next to the side access door. When manually activated, contact closure signal is provided to the ship's system which sounds an alarm.

The Halon discharge nozzle is located inside the enclosure. It is mounted on the underside of the crossbeam under the compressor front frame.

This one nozzle provides both initial and standby Halon discharge. The fire extinguish inhibit switch is mounted above the fire alarm pushbutton. When in the INACTIVE position, this switch provides a signal to the ship's system. This is used to prevent discharge of the fire extinguishing agent.

Fire may be sensed by the flame detectors (figure 5-45) or the temperature switches detect enclosure temperature above preset limits. It also may be detected by the manual fire alarm pushbutton. If it is activated, an alarm sounds. Panel indicator lights also inform the ship's operator of the condition.

A fire in either enclosure is extinguished by filling the enclosure with Halon. The ship's PCC has a Halon FLOOD pushbutton for each enclosure. To prevent an enclosure from being flooded with Halon while personnel are inside, use the safety disable switch (fire extinguish inhibit). This is located next to the enclosure access door and is positioned to INACTIVE.

Activation of the FLAME DET ALARM/HALON FLOOD switch on the PCC will provide the initial Halon discharge of 20 pounds at a rate of 1.45 lb/sec. An additional 20 pounds, with the same rate of discharge, is available on standby.

SUMMARY

In this chapter we have described the construction of the LM2500. You have learned about the engine description as well as the components that support the engine operation. This information is provided to give you, the GSE, an understanding of where these components are located. It also will help you understand the operation of the engine which we will discuss in the next chapter. This chapter has been thorough in describing the engine. However, you should always refer to the manufacturers' technical manuals before performing any maintenance on the LM2500.

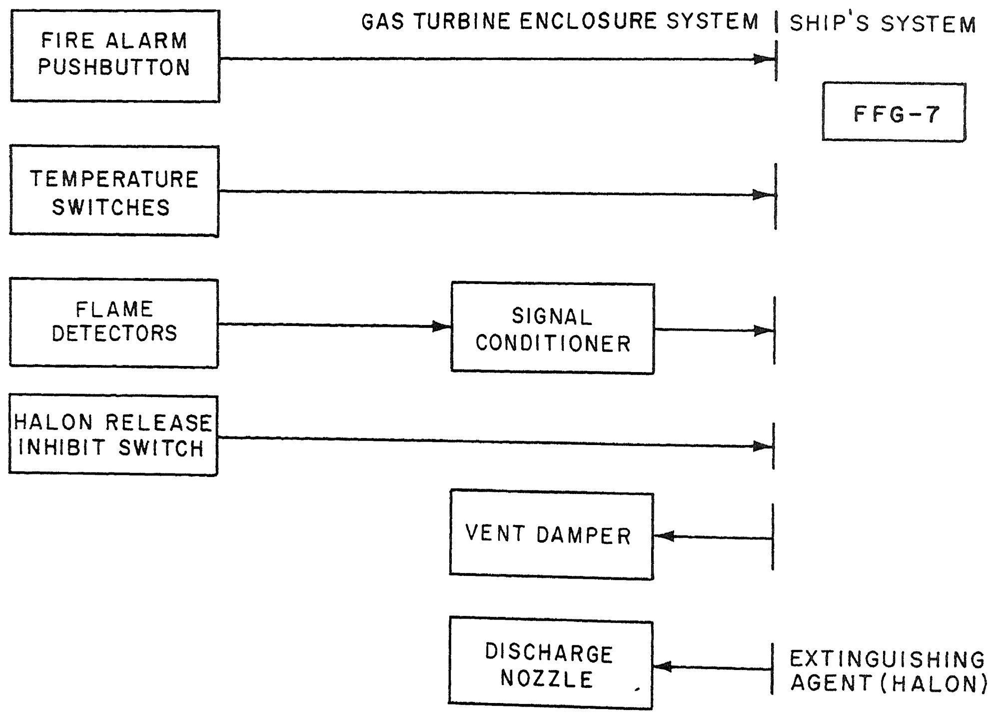

Figure 5-45.—Fire system block diagram, FFG-7.

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CHAPTER 6

LM2500 GAS TURBINE ENGINE OPERATION

To recognize problems with the LM2500, you must first understand its operation. In chapter 5 we discussed the construction of the LM2500. In this chapter we will discuss the operation of the engine from the local operating stations. We will cover the modes of operation, the control stations, and basic engine procedures and parameters related to the control stations. The operational limits and engine operating procedures are similar on all gas turbine powered ships. The control systems on the different classes do vary, though, causing some differences in modes of control and types of automatic operations. For this reason we will separately discuss each control console and its operations.

After reading this chapter and completing the associated assignments, you should understand the differences in engine control stations. You should also be able to identify the operating procedures and parameters of each engine control station. Also, you should have a basic understanding of the procedures for normal and emergency operation of the LM2500.

Keep in mind that the operations described in this chapter are presented to form a basis for your understanding the LM2500 operation. When actually operating any engineering equipment, you must always follow the EOSS. The EOSS is a step-by-step procedure. Its use is mandated by fleet commanders. Failure to use this very important document can cause casualties to very expensive and vital ship's equipment. Even the most experienced engineer uses the EOSS to start or stop equipment.

OPERATING STATIONS

Operation of main propulsion gas turbines is done from several different locations. The major classes of Navy ships that use the LM2500 engine have three control points. The first control station is in the engine room. This is known as the local operating panel (LOP) on the FFG-7 class. It is known as the propulsion local control console (PLCC) on all twin shaft gas turbine ships such as the DD-963 class. The engine-room control consoles are the *primary control consoles.* This is not to say that the engine-room console is in control most of the time. What is meant by primary is it may take control from any other remote station. For example, a ship is being operated with the throttle control at the pilothouse. However, the engine-room operator places the throttle control to local. Automatically, the engine room assumes control of the throttle operation.

The next level of control is in the central control station (CCS). This will be discussed in depth in later chapters. CCS is normally the control station for starting, stopping, and monitoring the LM2500. On the FFG-7 class ships this station is known as the propulsion control console (PCC). On the twin shaft ships the main engine control is known as the propulsion and auxiliary control console (PACC).

The third level of control is on the bridge. This station, known as the ship control console (SCC), may have direct throttle control of the engineering plant. (This control is done in the integrated or programmed control.) It allows the officer of the deck (OOD) to have direct throttle and pitch control. This eliminates the need for an engine order to be passed to central control and allows quicker maneuvering of the ship.

In the next section we will discuss the different local consoles used for LM2500 operation. Remember to refer to the EOSS any time you are operating at any of these stations.

ENGINE-ROOM CONTROL CONSOLES

As we discussed earlier, the engine-room console is the primary operating station for the LM2500. The primary purpose of the engine-room consoles is to allow you to operate an engine room independent of all other control points. If the SCC or CCS is damaged, you could still control the engines from the engine room. These consoles are also used as maintenance stations for operations such as water washing and as a central monitor for many engine-room parameters.

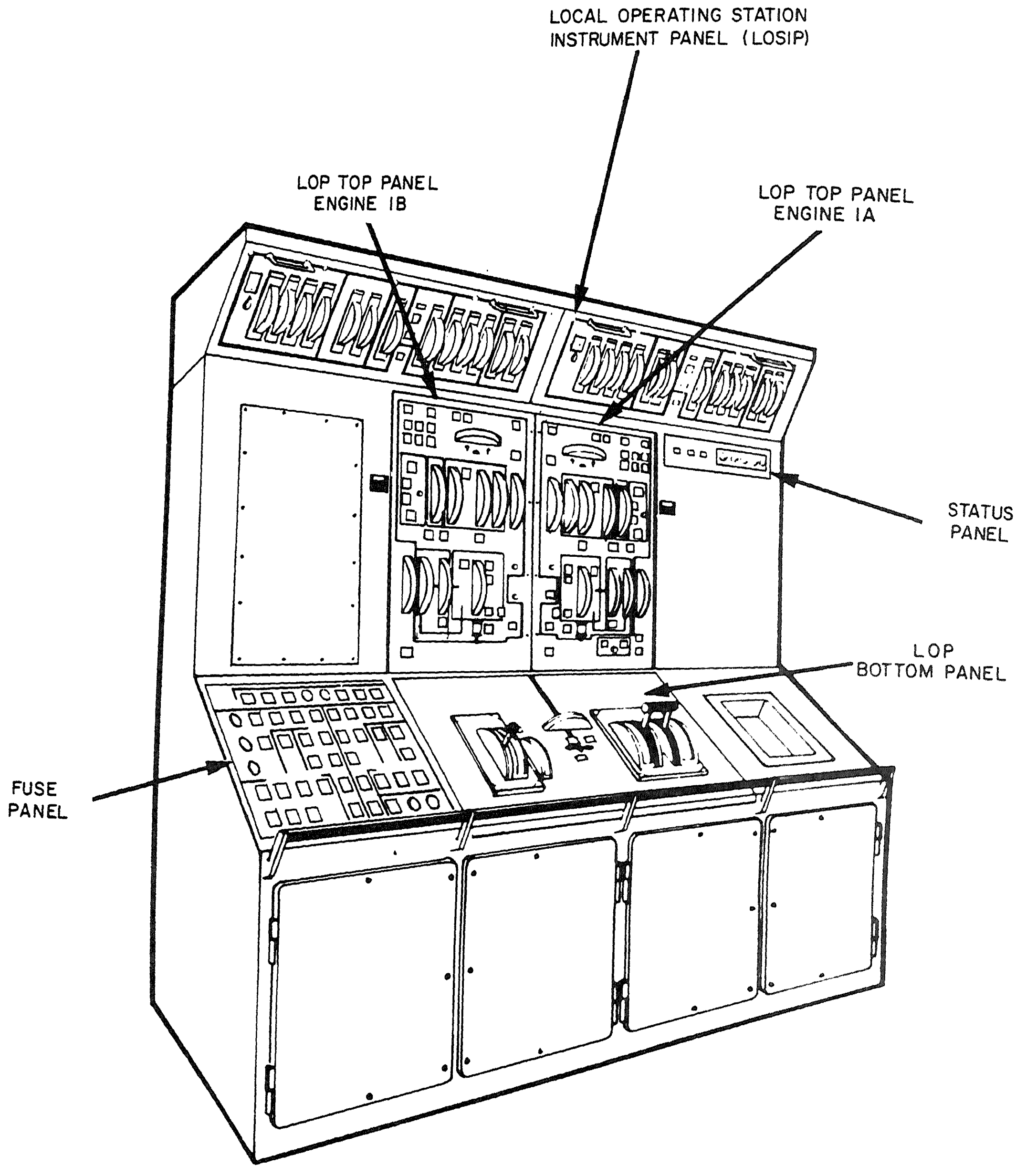

Figure 6-1.—FFG-7 LOP controls and displays.

293.29

LOCAL OPERATING PANEL

The LOP (figure 6-1) is the engine-room console on the FFG-7 class ship. It is located in the engine room near the propulsion equipment. The LOP has the necessary controls and indicators to permit direct local (manual) control of the propulsion equipment. The direct local mode of control, although still electronic, permits operation of the equipment independent of the programmed sequence from the computer. It is normally an unmanned console. However, you can use it in the event of an emergency or for control during maintenance. You may find it easier to understand the operational procedures for the LM2500 by following the operation of the programmed sequence. For this reason, we will discuss FFG-7 LM2500 operational procedures in more detail when discussing the PCC in chapter 10.

The LOP is divided into the following six sections.

1. Local operating station instrument panel (LOSIP)
2. LOP top panel engine 1A
3. LOP top panel engine 1B
4. Status panel
5. LOP bottom panel
6. Fuse panel

Local Operating Station Instrument Panel

The LOSIP (figure 6-2) is located at the top of the LOP. The LOSIP is divided into two sections, one for each engine. Their layouts are identical. The LOSIP has no control functions. It is only a monitoring panel. It is used to monitor conditions of the systems of the LM2500 and selected engine parameters.

As shown on figure 6-2, from left to right the sections monitored are lube oil (section A), fuel (section B), throttle (section C), enclosure (section D), GG (section E), and PT (section F). Please follow figure 6-2 as we discuss the six sections of the LOSIP. The parenthetical letters are indicated on figure 6-2.

LUBE OIL MONITORING.—The lube oil section (A) is used to monitor the parameters associated with the LM2500 lube oil system. The selector switch on the left is a five-position switch used to select the scavenge temperature (temp) to be monitored. It is used in conjunction with the scavenge temp meter located next to it. You can select either the A through D sumps or the gearbox scavenge oil temp by moving the selector switch. The second meter is used to monitor the scavenge filter (located on the LOSCA) differential pressure. The third meter indicates the LOSCA tank level. The last lube oil meter is used to indicate differential pressure across the lube oil supply filter (located in the module).

FUEL SYSTEM MONITORING.—The fuel section (B) monitors the fuel system of the engine. It has two meters to monitor fuel filter differential pressure (the engine-mounted filter) and fuel inlet temperature.

THROTTLE MONITORING.—The throttle meter section (C) indicates the percentage of engine power. It is in increments of 0 to 100 percent.

ENCLOSURE MONITORING.—The enclosure section (D) has two indicators. One is for the status of the vent damper OPEN/CLOSED. The other indicator is for the UV sensors in the enclosures. This indicator reads FLAME, indicating that a flame has been sensed in the module. There is also a meter in this section for the temperature of the enclosure. A lamp test button is located below the two indicators. This is used to test the bulbs in the two indicators.

GAS GENERATOR MONITORING.—The next section (E) is used to monitor the GG. It has three meters. The first one monitors inlet air pressure (P_{t2}), the pressure of the air entering the compressor. The center meter monitors the compressor air inlet temperature (T_2). The right meter monitors the compressor air discharge pressure (CDP).

POWER TURBINE MONITORING.—Two meters are used to monitor PT parameters (F). The left-hand meter is used to measure PT inlet pressure ($P_{t5.4}$). The second meter is used to monitor GG pressure ratio.

LOP Top Panel

The LOP top panel is divided into two sections, the engine 1A and engine 1B sections. Refer to figure 6-3 as we discuss the LOP top panel of

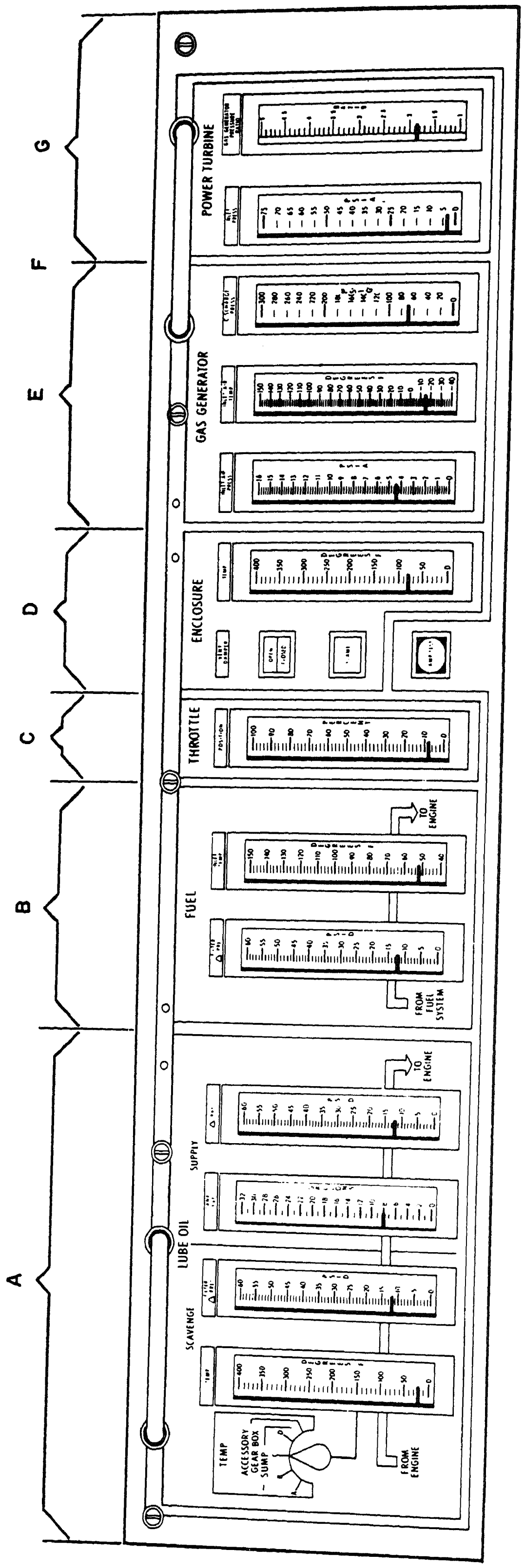

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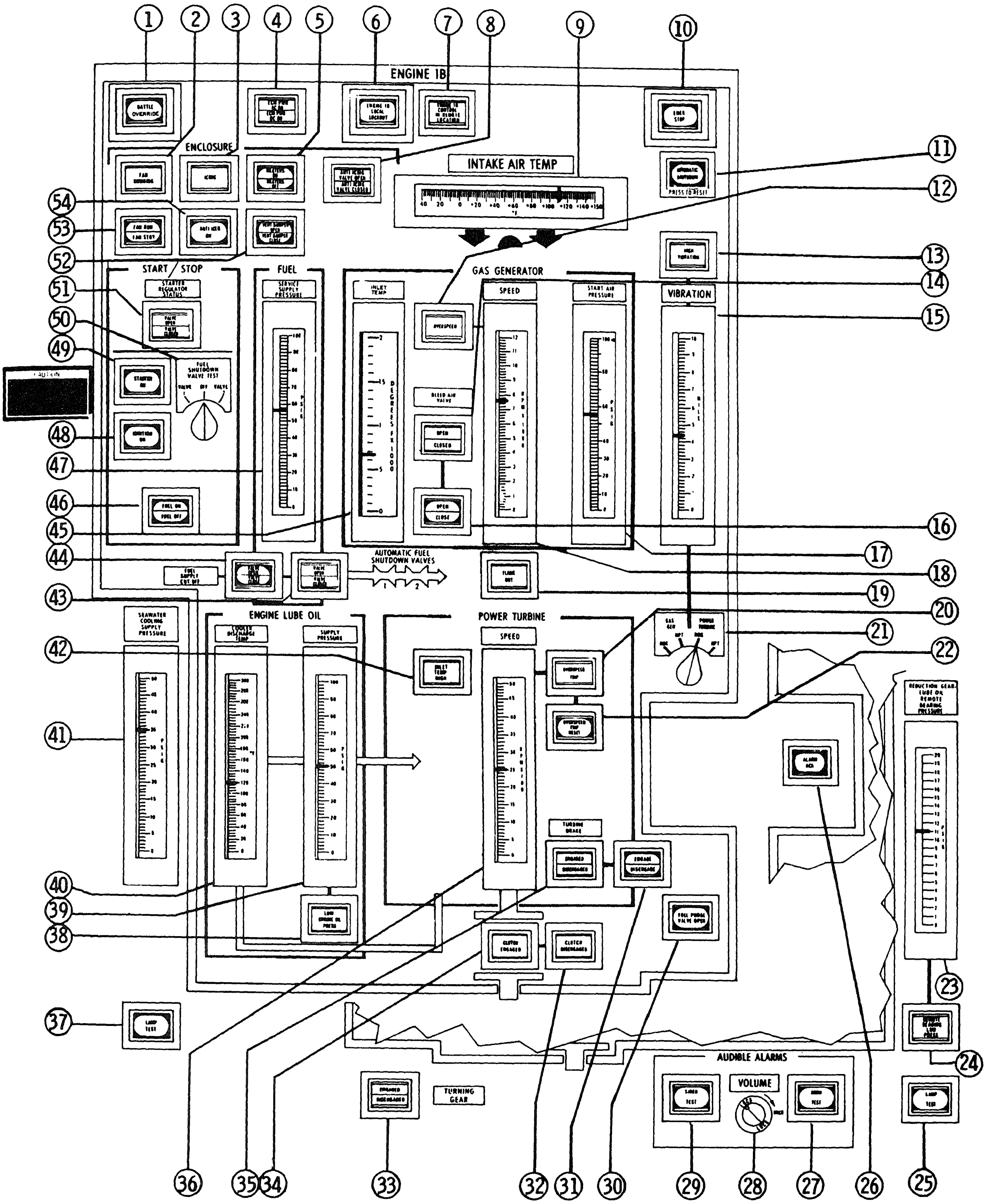
Figure 6-2.—FFG-7 local operating station instrumentation panel.



293.31

Figure 6-3.—LOP top panel.

engine 1B. The parenthetical numbers are indicated on figure 6-3.

The LOP top panel is used to control either of the GTMs. Although the engines are controlled from this panel, the operations are in the manual mode. There are no computer functions at the LOP.

BATTLE OVERRIDE.—BATTLE OVERRIDE (1) is a guarded, illuminated pushbutton. You can use it at any time, regardless of the station in control. This switch overrides the following shutdowns.

1. GTM low lube oil pressure
2. High engine vibration
3. High $T_{5.4}$
4. Power lever angle failure for:
    a. PCS command signal out of limits
    b. PT shaft torque out of limits
    c. PT speed out of limits

It does not override a flameout or a PT overspeed trip.

ENCLOSURE SECTION.—The enclosure section monitors the module cooling and air intake system. A description of the function of each indicator in this section follows.

FAN RUNNING (2) indicates the enclosure fan is operating when illuminated.

FAN RUN/FAN STBY (53) turns the cooling fan on or returns it to a standby condition (off).

ICING (3) indicates the intake air is below 41 °F and the humidity is above 70 percent.

ANTI-ICER ON (54) illuminates to indicate a command has been sent to open the anti-icing valve. Depressing this button again will close the anti-icing valve.

HEATERS ON/HEATERS OFF (5) turns the enclosure heater on or off.

VENT DAMPER OPEN/VENT DAMPER CLOSE (52) opens or closes the vent damper.

ANTI-ICING VALVE OPEN/ANTI-ICING VALVE CLOSED (8) shows the status of the anti-icing valve.

ECM POWER INDICATOR.—The ECM PWR AC ON/ECM PWR DC ON indicator (4) is a split legend type. The upper half indicates a.c. power is on to the FSEE. This a.c. power is used for igniters, anti-icing, and fire detection. The lower half indicates d.c. power is on. This d.c. power is used for the FSEE electronics and the engine fuel valve control circuit.

ENGINE CONTROL PUSHBUTTON OR INDICATOR.—The ENGINE 1B LOCAL LOCKOUT pushbutton (6) places the LOP in control of the associated engine. This is used to take control from the PCC. It is a guarded type of pushbutton. By redepressing it, you can have the control of the engine transferred to the PCC. When the engine control is at the PCC, the ENGINE 1B CONTROL IN REMOTE LOCATION indicator (7) will illuminate.

EMERGENCY STOP PUSHBUTTON.—The EMER STOP pushbutton (10) is used to stop the engine in an emergency. It is a guarded type of pushbutton. You can activate the emergency stop pushbutton, regardless of what station has control. This pushbutton closes both engine fuel valves and causes the engine to shut down.

AUTOMATIC SHUTDOWN INDICATOR/PUSHBUTTON.—The AUTOMATIC SHUTDOWN indicator (11) indicates an emergency shutdown has occurred on the related engine. The automatic shutdowns are as follows:

1. PT inlet temp high ($T_{5.4}$) above 1530 °F
2. Engine lube oil pressure low below 6 psig
3. High GG vibration above 7 mils
4. High PT vibration above 10 mils
5. Flameout: $T_{5.4}$ less than 400 °F with fuel manifold pressure above 50 psig

When one of the above conditions is met, the automatic shutdown circuitry closes the two main fuel valves. You can push this pushbutton to reset the automatic shutdown circuitry, once the engine has come to a complete stop.

VIBRATION SECTION.—This portion has a meter, switch, and an indicator.

The VIBRATION meter (15) is always reading the vibration on the engine at the position selected by the switch.

The GAS GEN/POWER TURBINE switch (21) is a four-position switch. It allows you to look at the two different vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibration. A tracking filter for each pickup separates GG vibration from PT vibration depending on vibration frequency. Limits apply to frequency and not pickup location.

The HIGH VIBRATION indicator (13) will illuminate when the vibration on the GG reaches 4 mils, and the PT reaches 7 mils. An automatic shutdown occurs when GG vibration reaches 7 mils, and PT vibration reaches 10 mils.

GAS GENERATOR SECTION.—This section monitors parameters associated with the GG. It contains four meters, two indicators, and an illuminated pushbutton.

INTAKE AIR TEMP meter (9) monitors the temperature of the outside air. This meter is located above the intake air section.

START AIR PRESSURE meter (17) measures the pressure of the air used to start the engine.

The GG SPEED meter (18) monitors N_{GG}. The readings from this meter are multiplied by 1000 to determine GG speed. The OVERSPEED indicator (12) will illuminate when the speed of the GG exceeds 9700 ± 100 rpm.

The BLEED AIR VALVE indicator (14) displays the OPEN or CLOSED status of the engine's 16th-stage bleed air valve. A split indicator is used to display either the OPEN or CLOSED position. The bleed air OPEN/CLOSE pushbutton (16) controls the operation of the engine bleed air valve. It will illuminate either open or close depending on the command that is selected. The INLET TEMP meter (45) displays the $T_{5.4}$ of the PT. You have to multiply the number displayed by 1000 to determine the actual temperature.

FUEL SECTION.—The fuel section contains a meter, an indicator, and a pushbutton associated with the GTM fuel supply. The SERVICE SUPPLY PRESSURE meter (47) displays the fuel supply pressure from the ship's fuel system. The VALVE OPEN/VALVE CLOSE pushbutton (44) and VALVE OPEN/VALVE CLOSED indicator (43) control and display the status of the module fuel cutoff valve located under the enclosure.

START/STOP SECTION.—The start/stop section contains the controls to start and stop the GTM. The STARTER REGULATOR STATUS indicator (51) is a split indicator. It displays the open or closed status of the starter regulator valve. The STARTER ON pushbutton (49) is a momentary switch. It opens the starter regulator valve when depressed and closes it when released.

The IGNITION ON pushbutton (48) is also a momentary-type switch. When depressed, it turns the engine ignitors on; when released, the ignitors are turned off.

The FUEL ON/FUEL OFF pushbutton (46) is used to energize or de-energize the fuel shutdown valves. By depressing it once, you can open the fuel valves. Redepressing it closes the valves. You must always keep the pushbutton in the FUEL OFF position when control is at the PCC.

The FUEL SHUTDOWN VALVE TEST switch (50) is used to test each fuel valve. The switch is spring loaded to the OFF position. To test an individual valve, you must turn the switch to the desired valve and hold it. You must keep the switch held to that position until the N_{GG} is at zero. Then depress the FUEL ON/FUEL OFF pushbutton (46) to close the other valve and keep both valves closed.

SEAWATER COOLING METER.—The SEAWATER COOLING SUPPLY PRESSURE meter (41) is used to display the reduction gear cooler seawater supply pressure.

A LAMP TEST pushbutton (37) is located below the seawater cooling meter. It is used to test the lamps in this section of the LOP.

REDUCTION GEAR LUBE OIL REMOTE BEARING PRESSURE METER.—Figure 6-3 shows the LEFT LOP top panel. On the right panel a REDUCTION GEAR LUBE OIL REMOTE BEARING PRESSURE meter (23) displays the most remote bearing pressure. Below this is the REMOTE BEARING LOW PRESS indicator (24) which alerts the operator if the most remote bearing falls below 9 psig.

ENGINE LUBE OIL SECTION.—The engine lube oil section has two meters and an indicator to monitor the engine lube oil supply. The COOLER DISCHARGE TEMP meter (40) monitors the temperature of the LOSCA cooler outlet. The SUPPLY PRESSURE meter (39) monitors the engine lube oil supply pressure. The LOW ENGINE OIL PRESS indicator (38) located below this meter illuminates when the engine lube oil pressure is below 15 psig.

COMBUSTOR, POWER TURBINE, AND OUTPUT.—The FLAME OUT indicator (19) alerts you if conditions for a flameout exist. The condition occurs if the $T_{5.4}$ drops below 400°F when the fuel manifold pressure is above 50 psig. This also initiates an automatic shutdown.

The PT INLET TEMP HIGH indicator (42) illuminates to alert the operator of a high $T_{5.4}$. This will occur at 1500°F PT inlet temp.

The PT SPEED meter (36) is used to monitor the speed of the PT. Associated with this meter is an indicator and pushbutton. The PT OVERSPEED TRIP indicator (20) illuminates when an overspeed trip occurs. The indicator is set at 3960 ± 40 rpm. The OVERSPEED TRIP RESET pushbutton (22) resets the overspeed trip circuitry. Use this after an overspeed trip occurs. NOTE: Do not reset until the gas generator has come to a complete stop. If you do not, a post-shutdown fire may occur.

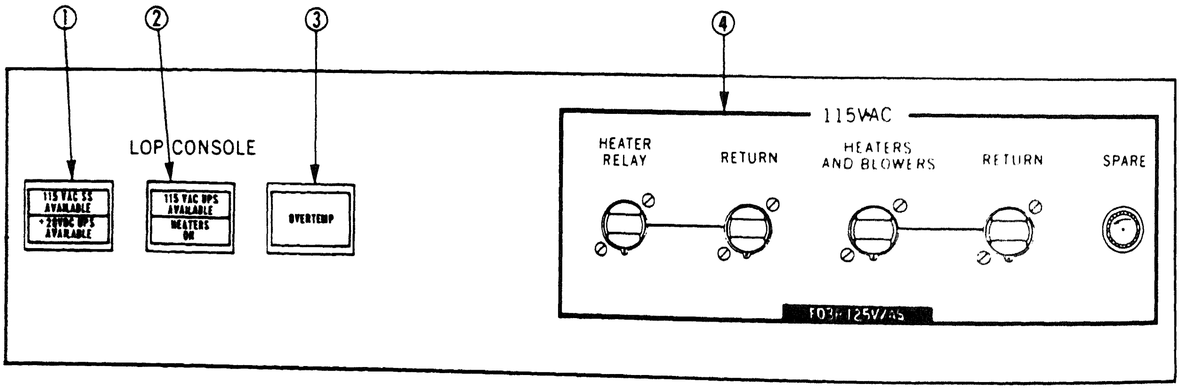
The TURBINE BRAKE section has a pushbutton (31) that controls the operation of the PT brake. It is a split indicator type of pushbutton. The indication illuminates the signal that is being sent to the turbine brake control, either ENGAGE or DISENGAGE. The TURBINE BRAKE indicator (35) is also a split-type indicator. It displays the actual position of the turbine brake, either ENGAGED or DISENGAGED.

The two clutch indication lights display the status of the GTM clutch. These indicators (32 and 34) display either CLUTCH ENGAGED (34) or CLUTCH DISENGAGED (32) status.

A FUEL PURGE VALVE OPEN pushbutton (30) operates the engine's fuel purge valve. Depressing this button opens the fuel purge valve. About 3 gallons of fuel will be drained from the engine system. In this way cold fuel is drained from the GTM before starting. Operate fuel purge only when the engine is rotating.

TURNING GEAR INDICATOR.—The TURNING GEAR indicator (33) shows the status of the MRG turning gear. This is a split-type indicator and displays either ENGAGED or DISENGAGED. It is located below the A engine section.

AUDIBLE ALARMS SECTION.—The AUDIBLE ALARMS section has the controls to adjust the alarm volume and test the horn and siren. The alarm VOLUME rheostat (28) adjusts the alarm volume. The alarm test pushbuttons



293.32

Figure 6-4.—LOP status panel.

HORN TEST (27) and SIREN TEST (29), are depressed to test the horn and siren.

LOP Status Panel

The LOP status panel (figure 6-4) is located to the right of the A engine top panel. It contains the indicators for LOP power supplies and the 115 volt a.c. fuses for console heaters and blowers. The parenthetical numbers in the following paragraphs are indicated on figure 6-4.

The first indicator (1) is a split indicator. It displays the status of 115 volt a.c. ship's service power and 28 volt d.c. power. These indicators will illuminate when each source of power is available. The second indicator (2) is also a split type. It displays the status of the 115 volt a.c. uninterruptible power supply (UPS) and the heaters on status. The third indication (3) displays console overtemperature.

The 115 volt a.c. fuse section (4) contains the fuses for the heater relay and power for the heaters and blowers.

LOP Bottom Panel

The LOP bottom panel (figure 6-5) contains the shaft operating and monitoring controls and indicators. Only manual throttle and pitch control is available at the LOP. The parenthetical numbers in the following paragraphs are indicated on figure 6-5.

The PITCH CONTROL (1) controls the pitch of the propeller. It is only operative when the LOP is in control of both engines. Associated with it is a PITCH indicator (2) which displays the actual propeller pitch. Above this meter is an ASTERN PITCH indicator (3). This illuminates when pitch is actually in the astern direction. The PROP HYDRAULIC PRESS LOW indicator (4) will alert you when the CPP hydraulic pressure system is below 40 psig.

The SHAFT BRAKE indicator (5) and control (7) control and monitor the shaft brake. When you depress the shaft brake control button, it will illuminate the command selected. The shaft brake will only activate when the following permissives are met.

- Pitch at zero
- Shaft speed below 75 rpm
- Throttles at idle
- Station in control

The SHAFT BRAKE indicator (5) will display the actual status of the shaft brake, either ENGAGED or DISENGAGED.

The SHAFT SPEED meter (6) displays the speed of the shaft in rotations per minute (rpm).

The REMOTE THROTTLE CONTROL levers (8) control the power level of each GTM. The throttles are controlled in increments of percent power.

LOP Fuse Panel

The LOP fuse panel (figure 6-6) is located on the lower left section of the LOP. It contains the 28 volt d.c. fuses for the LOP, the enclosures, and the transducers that input the LOP.

PROPULSION LOCAL OPERATING EQUIPMENT

The propulsion local operating equipment (PLOE) is the engine-room control equipment on DD-963, DDG-993, and CG-47 class ships. Two identical PLOEs are on each ship, one in each engine room. PLOE number 1 is located in main engine room (MER) 2 while PLOE number 2 is in MER 1. Each PLOE has two units. The major component is the propulsion local control console (PLCC). The PLCC is the local operating station. The second unit is the propulsion local control electronic enclosure (PLCEE). This unit contains the power supplies for the PLCC. Other than on/off control, there are no operator functions at the PLCEE.

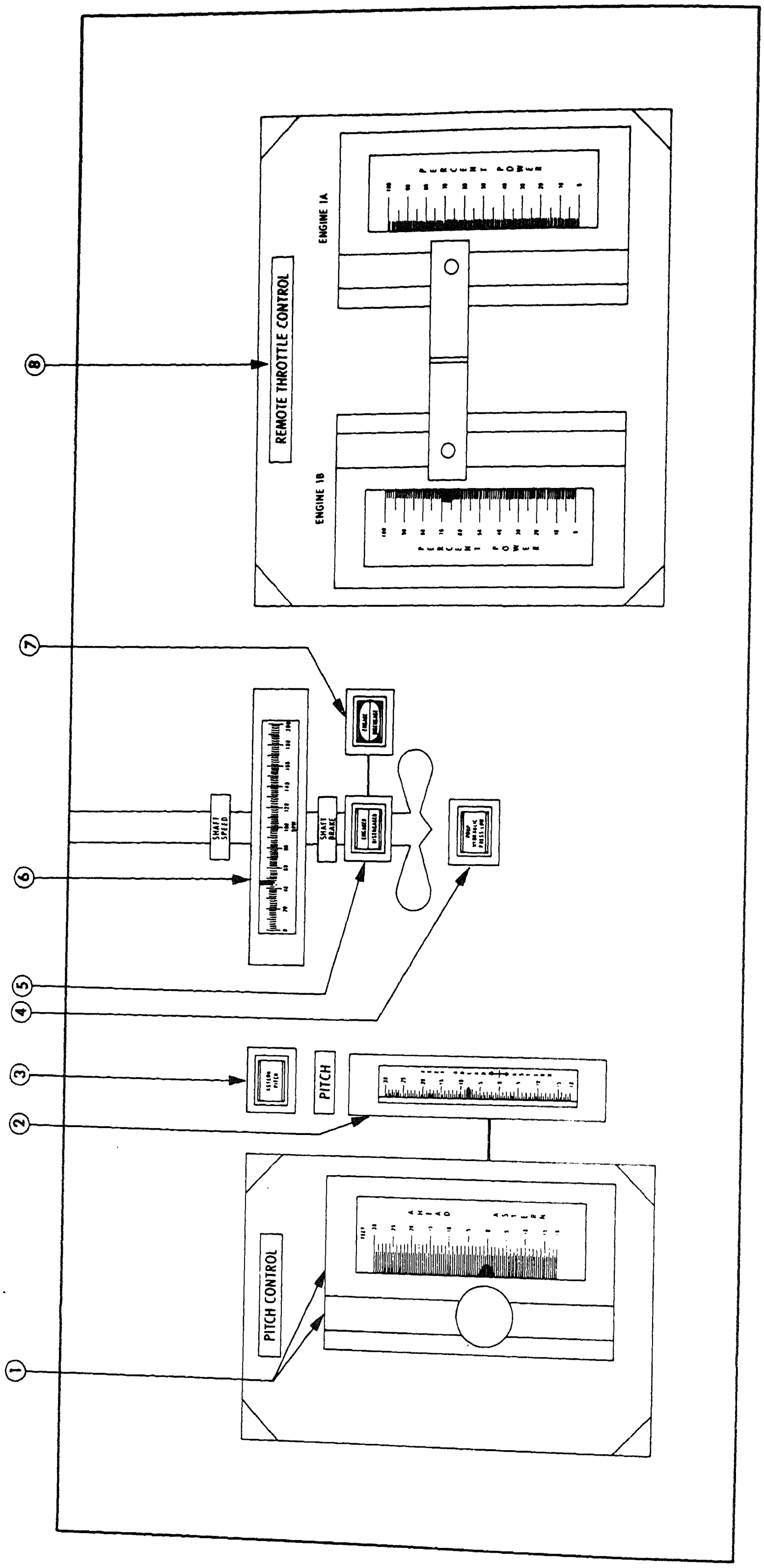


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Figure 6-5.—LOP bottom panel.

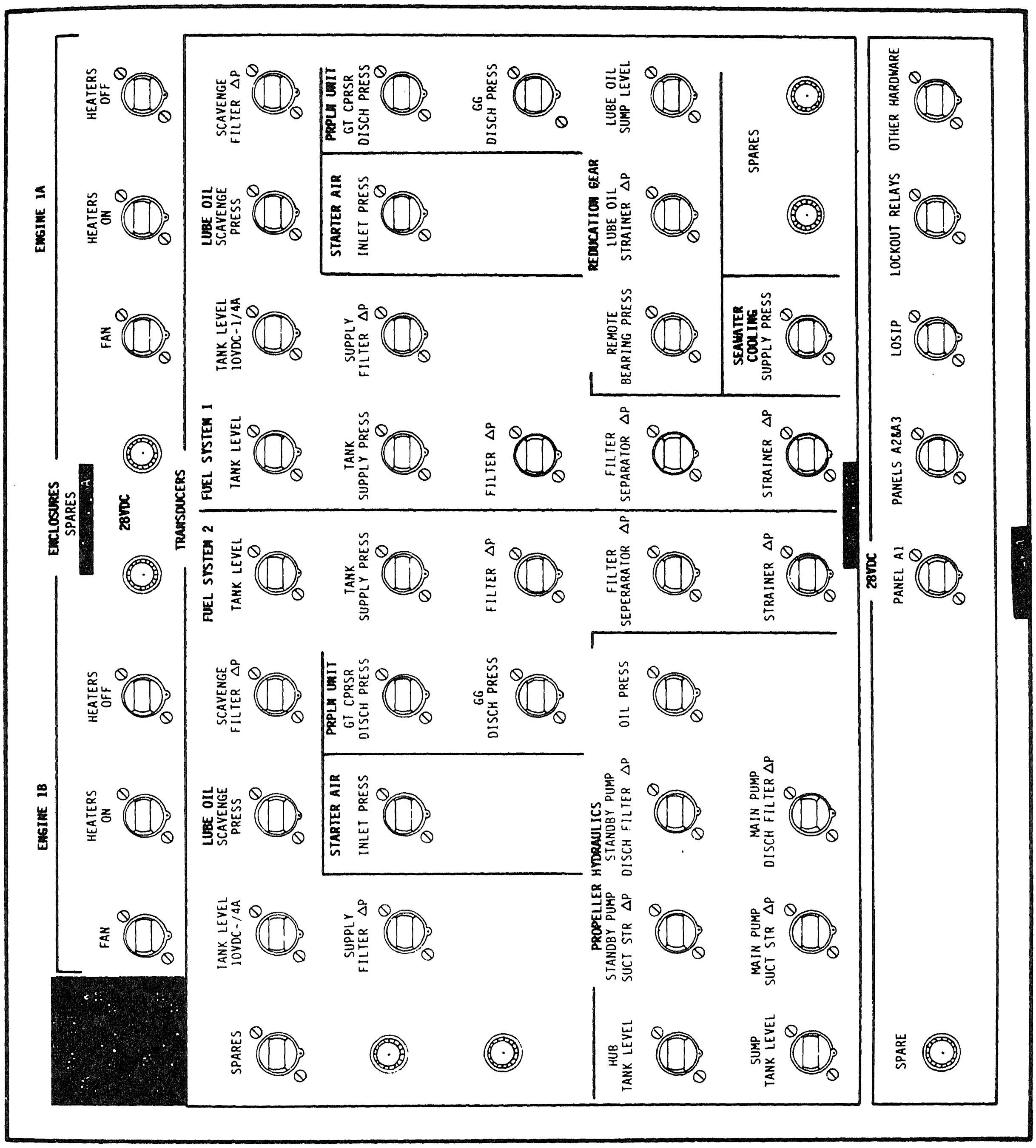
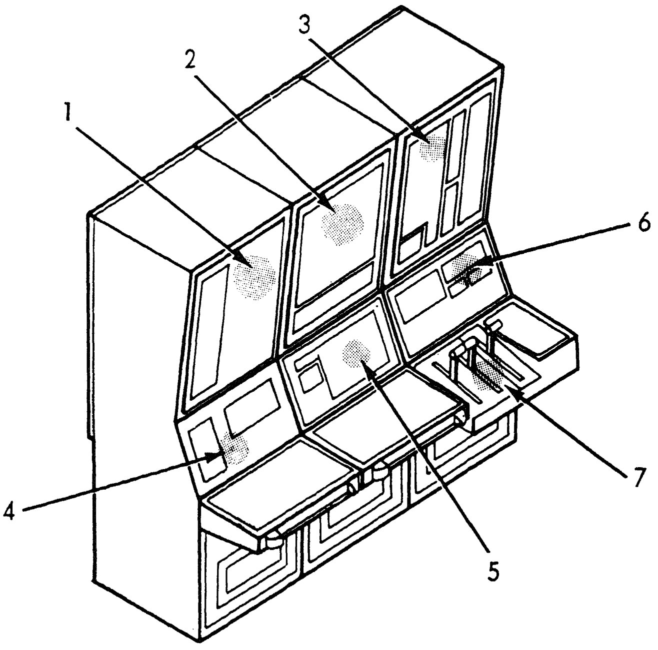


Figure 6-6.—LOP fuse panel.



1. FUEL OIL/GTM B PANEL
2. GTM A/B PANEL, BLEED VALVE CONTROLS
3. MAIN REDUCTION GEAR, CRPP, GTM A PANEL
4. SELF-TEST PANEL/GTM B START STOP MODE CONTROLS
5. EOT/ALARM ACKNOWLEDGE PANEL
6. ALARM TEST PANEL/ GTM A START STOP MODE CONTROLS
7. THROTTLE CONTROLS

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Figure 6-7.—Propulsion local control console—major sections.

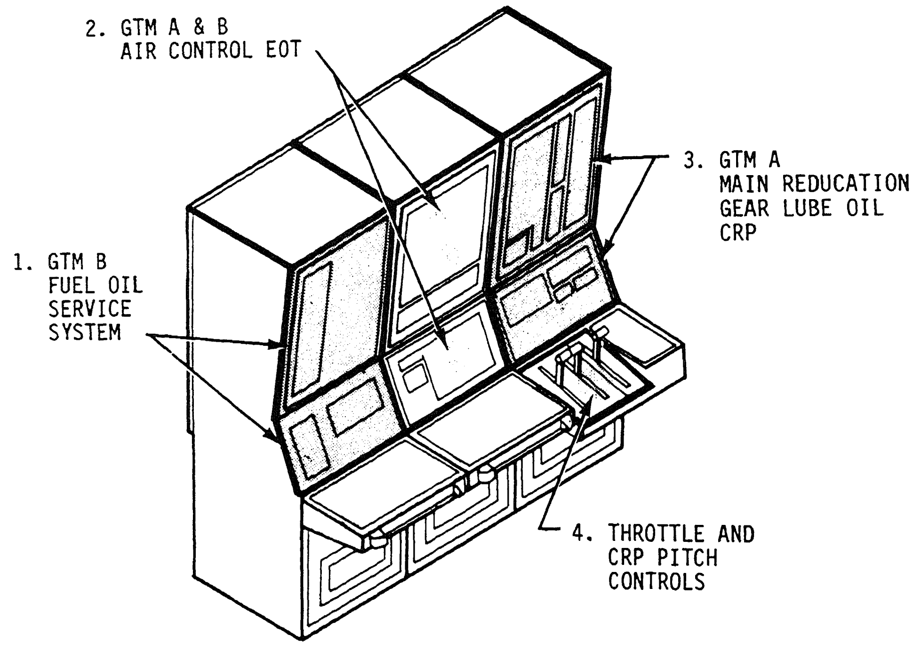

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Figure 6-9.—Propulsion local control console—panel arrangement.

Propulsion Local Control Console

The PLCC is divided into six panels. Figure 6-7 illustrates the console and the six panels. Figure 6-8 (foldout at the end of this chapter) is a more detailed view of the console's six panels.

Each PLCC has the principal electronics necessary for controlling and monitoring the propulsion plant within that engine room. The console is arranged in a logical layout into four major sections (figure 6-9). Please follow the illustrations of the console from left to right as we discuss the sections and their purposes.

1. The GTM B and the FUEL OIL SERVICE SYSTEM section has the controls and status indicators for GTM B and the controls, status indicators, and alarm indicators for the FO service system.
2. The GTM A and B, AIR CONTROL, and ENGINE ORDER TELEGRAPH (EOT) section has the alarm indicators for GTMs A and B, the controls and alarm indicators for starter (bleed) air, and the EOT.
3. The GTM A, MAIN REDUCTION GEAR LUBE OIL, and CONTROLLABLE REVERSIBLE PITCH PROPELLER section has the controls and status indicators for GTM A; the controls, status indicators, and alarm indicators for the MRG lube oil system; and the controls, status, and alarm indicators for the controllable reversible pitch (CRP) propeller system.
4. The THROTTLE AND CRP PITCH CONTROLS section has the power level angle throttle controls and the propeller pitch control.

FUEL OIL SERVICE SYSTEM.—The FO subpanel (figure 6-10) is located on the upper left panel of the console. For easier description the indicator section is divided into columns with row numbers beside the A column. A description of the indicators and the parameters to activate them follows (the indicator colors are in parentheses).

A-1. PUMP B FAULT (red). The pump must be running and the discharge pressure less than 35 psig for 9 seconds

A-2. TANK B TEMP HI/LO (red). HI 130°F, LO 60°F

A-3. Blank

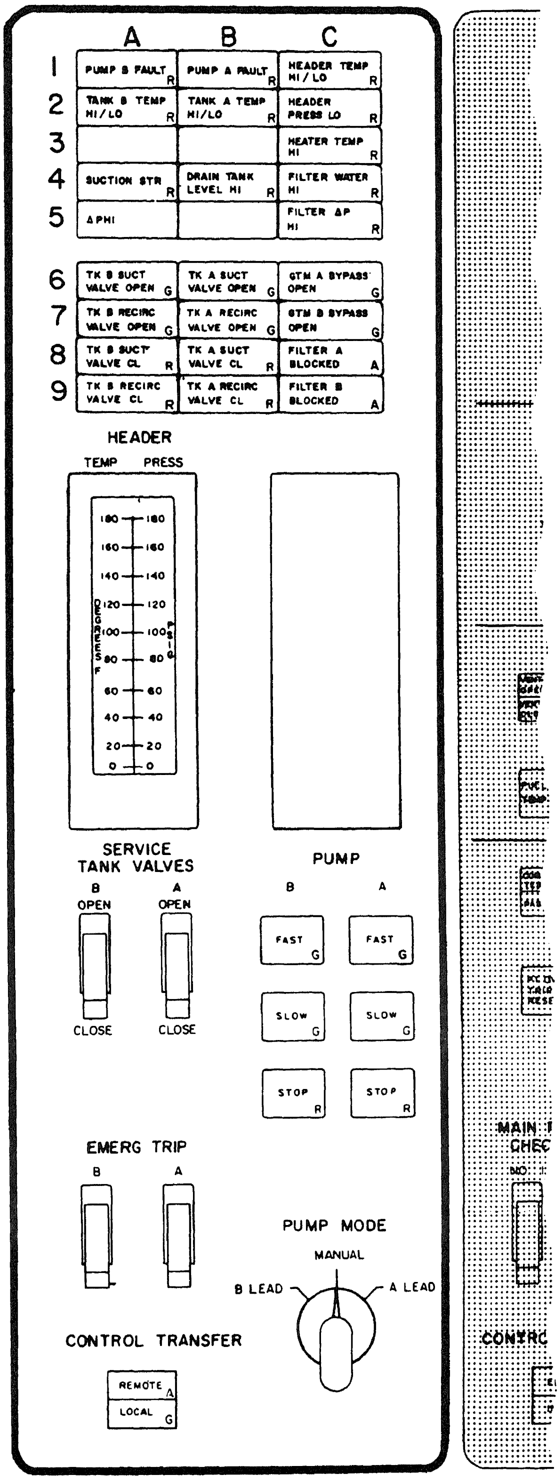

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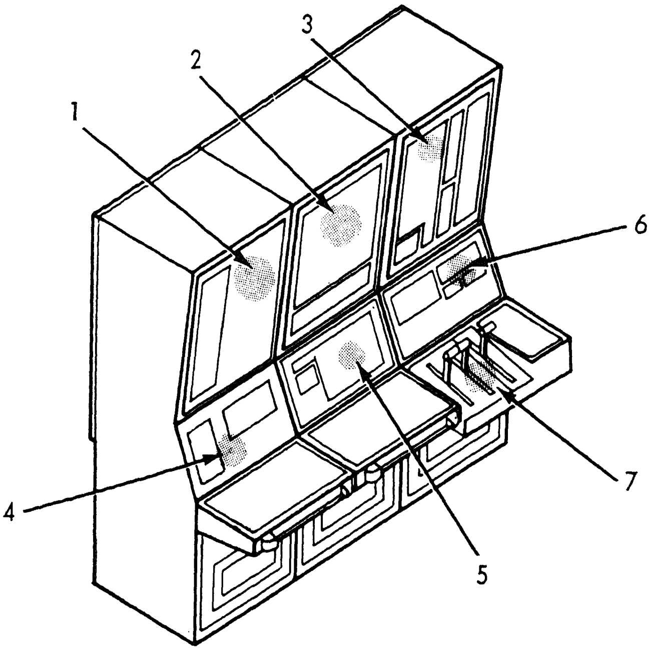
Figure 6-10.—Fuel oil service system—controls and indicators.



1. FUEL OIL/GTM B PANEL
2. GTM A/B PANEL, BLEED VALVE CONTROLS
3. MAIN REDUCTION GEAR, CRPP, GTM A PANEL
4. SELF-TEST PANEL/GTM B START STOP MODE CONTROLS
5. EOT/ALARM ACKNOWLEDGE PANEL
6. ALARM TEST PANEL/ GTM A START STOP MODE CONTROLS
7. THROTTLE CONTROLS

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Figure 6-7.—Propulsion local control console—major sections.

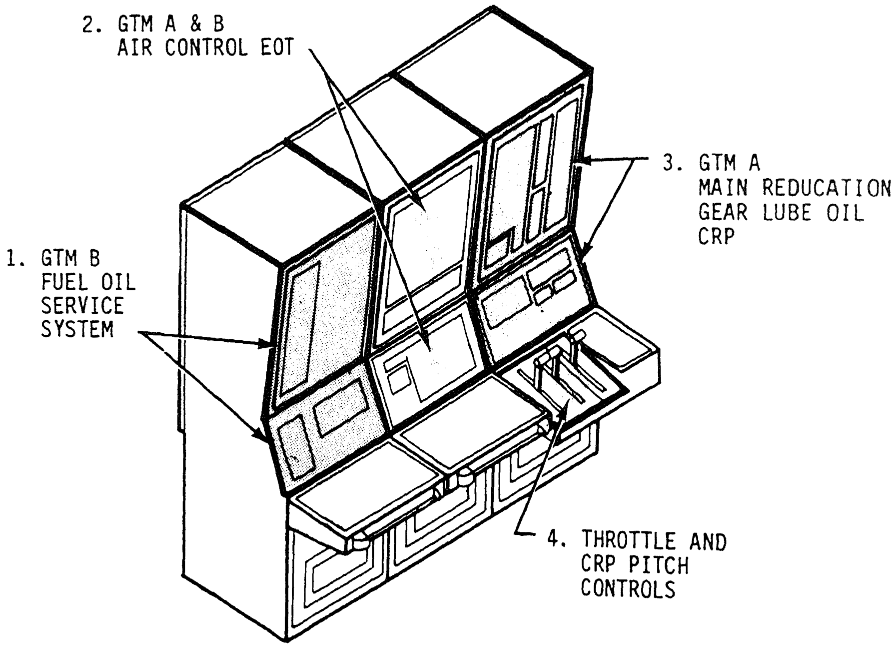

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Figure 6-9.—Propulsion local control console—panel arrangement.

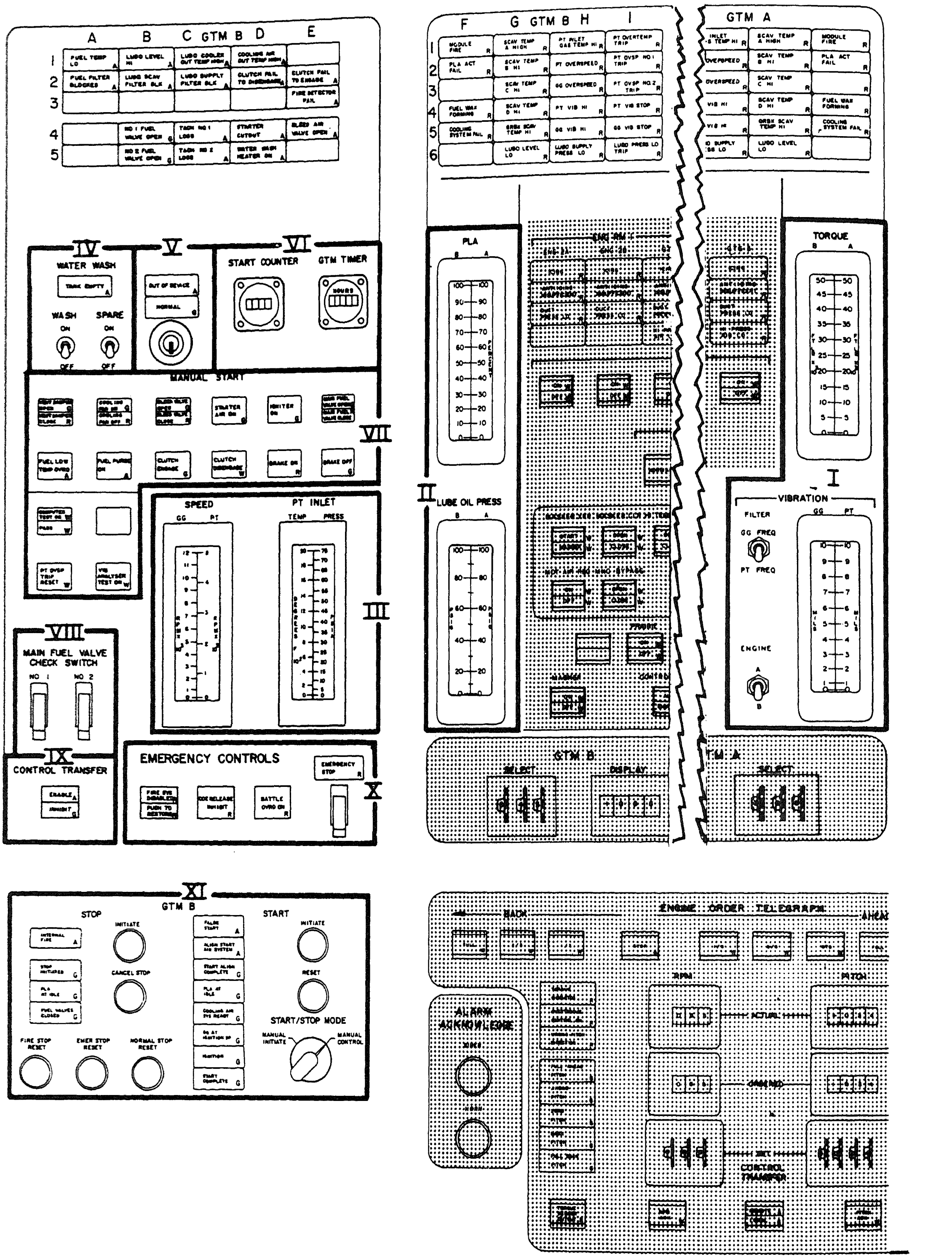

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Figure 6-11.—GTM B controls and indicators.

A-4. SUCTION STR ΔP HI (red). 4 psid

A-5. Blank

A-6. TK B SUCT VALVE OPEN (green)

A-7. TK B RECIRC VALVE OPEN (green)

A-8. TK B SUCT VALVE CL (red)

A-9. TK B RECIRCL VALVE CL (red)

B-1. PUMP A FAULT (red). Same as A-1

B-2. TANK A TEMP HI/LO (red). Same as A-2

B-3. Blank

B-4. DRAIN TANK LEVEL HI (red). 2.5 gallons in the leak detection tank

B-5. Blank

B-6. TK A SUCT VALVE OPEN (green)

B-7. TK A RECIRC VALVE OPEN (green)

B-8. TK A SUCT VALVE CL (red)

B-9. TK A RECIRC VALVE CL (red)

C-1. HEADER TEMP HI/LO (red). HI 130 °F, LO 80 °F

C-2. HEADER PRESS LO (red). 40 psig

C-3. HEATER TEMP HI (red). 140 °F

C-4. FILTER WATER HI (red)

C-5. FILTER ΔP HI (red). 30 psid across the coalescer

C-6. Blank

C-7. Blank

C-8. FILTER A BLOCKED (amber). 25 psid across the A tower of the coalescer

C-9. FILTER B BLOCKED (amber). 25 psid across the B tower of the coalescer

The following is a description of the other controls which are a part of the FO control panel.

HEADER (TEMP AND PRESS) METER indicates the system temperature at the heater outlet and system pressure at the filter/coalescer outlet. This meter is independent of other electronics and operates even if other alarm circuitry is inoperative.

SERVICE TANK VALVES are covered toggle control switches. They command the fuel tank suction and recirculation valves open or closed.

PUMP is a set of control pushbuttons that control pump speed for both pumps.

EMERG TRIP are covered toggle control switches that command the emergency FO trip valves closed (you must open them manually).

PUMP MODE is a rotary select switch that allows for manual or automatic control of the fuel pumps. It selects the lead (primary) and standby pump.

CONTROL TRANSFER is a pushbutton control switch that transfers control of the FO system to the central control station.

GTM CONTROLS AND INDICATORS.— The GTM controls and alarm/status indicators are located toward the center of the console (figure 6-8 foldout). The controls and indicators for GTM B are on the left side of the console with the controls and indicators for GTM A on the right side.

Refer to figure 6-11, GTM B controls and indicators, and figure 6-12, GTM sensing points with controls and indicators, as we identify the GTM indicators and the parameters to activate them.

A-1. FUEL TEMP LO (amber) 80 °F

A-2. FUEL FILTER BLOCKED (amber) 27 psid

A-3, 4, 5. Blank

B-1. LUBO LEVEL HI (amber) 40 gallons

B-2. LUBO SCAV FILTER BLK (amber) 20 psid

B-3. Blank

B-4. No. 1 FUEL VALVE OPEN (green)

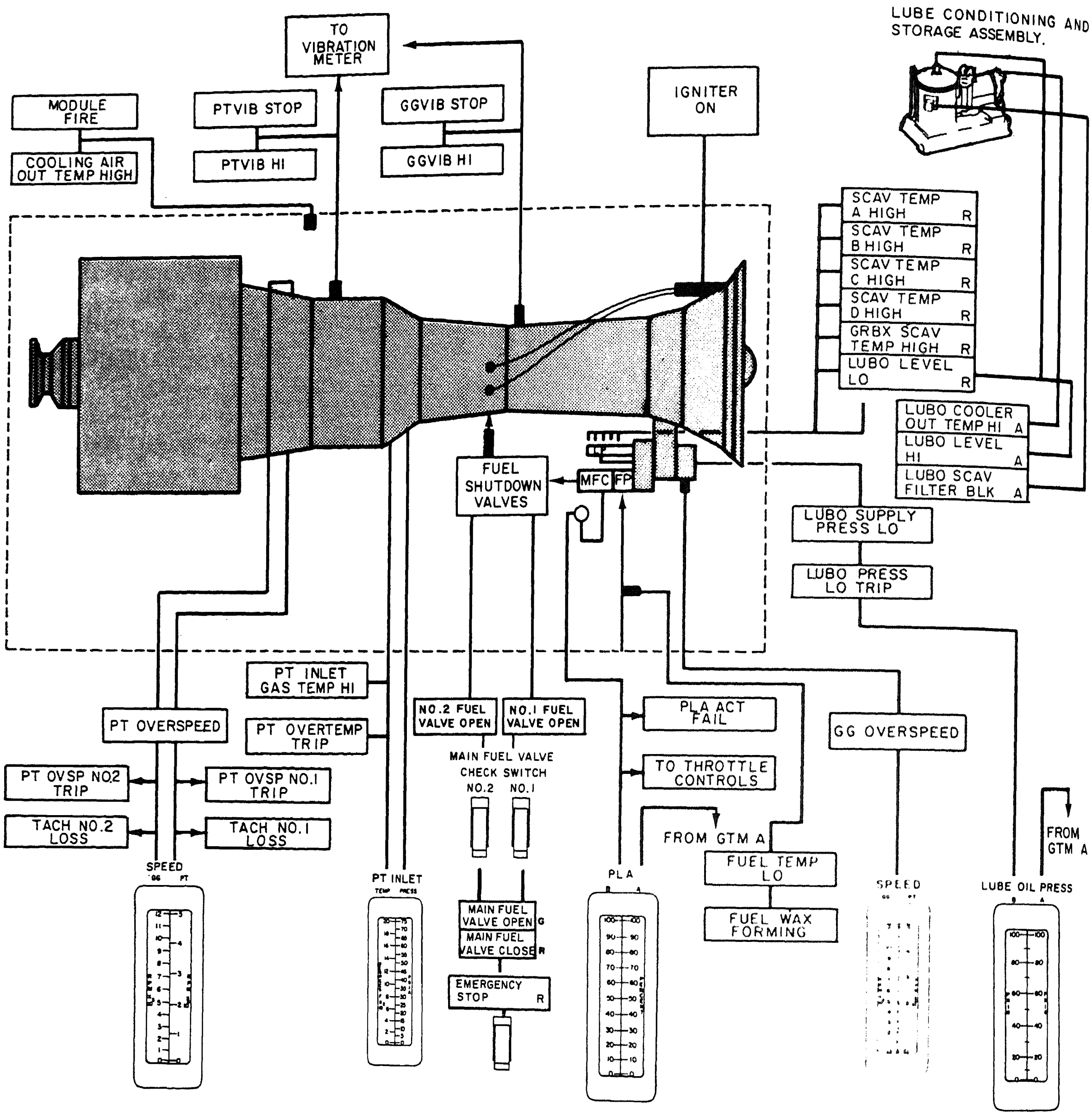

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Figure 6-12.—GTM sensing points.

B-5. No. 2 FUEL VALVE OPEN (green)

C-1. LUBO COOLER OUT TEMP HIGH (amber) 250 °F

C-2. LUBO SUPPLY FILTER BLK (amber) 20 psid

C-3. Blank

C-4. TACH No. 1 LOSS (amber). Power turbine speed (N_2) less than 100 rpm

C-5. TACH No. 2 LOSS (amber). Power turbine speed (N_2) less than 100 rpm

D-1. COOLING AIR OUT TEMP HIGH (amber) 350 °F

D-2. CLUTCH FAIL TO DISENGAGE (amber)

D-3. Blank

D-4. STARTER CUTOUT (amber)

D-5. WATER WASH HEATER ON (amber). (Not used)

E-1. Blank

E-2. CLUTCH FAIL TO ENGAGE (amber)

E-3. FIRE DETECTOR FAIL (amber). GTM fire sensor malfunction

E-4. BLEED AIR VALVE OPEN (amber)

E-5. Blank

F-1. MODULE FIRE (red). Flame detected by fire sensor or 400 °F sensed by temperature switch

F-2. PLA ACT FAIL (red). Power level angle actuator voltage out of limits or an overtorque condition exists

F-3. Blank

F-4. FUEL WAX FORMING (red). Fuel temperature at the MFC is less than 60 °F

F-5. COOLING SYSTEM FAIL (red). The cooling system fan pressure is out of limits or vent damper is not open

F-6. Blank

G-1. SCAV TEMP A HIGH (red) 300 °F

G-2. SCAV TEMP B HIGH (red) 300 °F

G-3. SCAV TEMP C HIGH (red) 300 °F

G-4. SCAV TEMP D HIGH (red) 300 °F

G-5. GRBX SCAV TEMP HIGH (red) 300 °F

G-6. LUBO LEVEL LO (red) 8 gallons

H-1. PT INLET GAS TEMP HIGH (red) 1500 °F ($T_{5.4}$)

H-2. PT OVERSPEED (red) 3700 rpm

H-3. GG OVERSPEED (red) 9700 rpm

H-4. PT VIB HIGH (red) 7 mils

H-5. GG VIB HIGH (red) 4 mils

H-6. LUBO SUPPLY PRESS LOW (red) 15 psig

I-1. PT OVERTEMP TRIP (red) 1530 °F ($T_{5.4}$)

I-2. PT OVSP No. 1 TRIP (red) 3960 ± 40 rpm

I-3. PT OVSP No. 2 TRIP (red) 3960 ± 40 rpm

I-4. PT VIB STOP (red) 10 mils

I-5. GG VIB STOP (red) 7 mils

I-6. LUBO PRESS LOW TRIP (red) 6 psig

Refer to figures 6-11 and 6-12 as we describe the meters on the local control console. (The meters in Sections I and II are common. One side is used for GTM A and one side is used for GTM B. The meters in Section III are dual purpose meters but monitor only one GTM.)

Section I

Torque — The signals come from the GTM and are conditioned by the FSEE (torque computer section) and sent to the console for display. The torque meter reads in lb/ft and is the torque output of the power turbine.

Vibration — The signals come from vibration pickups on the LM2500. There are two pickups, one on the PT and one on the GG

Vibration—Continued

(figure 6-12). This meter has an engine select switch that allows you to select the engine to be monitored. This select switch and the meter do not affect the vibration high and vibration stop alarms described earlier. Another switch allows you to check the vibration at each frequency level. The vibration meter reads in mils (0.001 in.) peak to peak.

Section II

PLA — The signal comes from the PLA actuator and is sent to the console for display. The PLA meter reads in percentage of travel. This percentage is equal to degrees of travel of the power lever. 0% = 13° on DD-963, DDG-993, and CG-47. 0% = 13.5° on FFG-7. 100% = 113.5° on all classes.

Lube Oil Press — The signal comes from the lube oil pump, supply side (pump discharge), and is sent to the console for display. The lube oil pressure meter reads in psig.

Section III

PT Inlet — The signals come from the sensors in the turbine mid frame. The temperature sensors are thermocouples, and the pressure sensors are probes that pressurize a transducer. The temperature meter reads in degrees Fahrenheit, and the pressure meter reads in psia.

Speed — The signals originate at the GG and the PT, see figure 6-12. The GG speed pickup is located on the accessory gearbox. The PT speed pickups (2) are located in the turbine rear frame. The speed meter reads in rpm.

The next parts of the console to be discussed are the control sections, Sections IV through XI in figure 6-11.

Section IV

Water Wash — TANK EMPTY—shows the water wash tank is empty of water wash or rinse solution.

WASH ON/OFF—is a toggle switch that opens or closes the water wash solenoid valves.

SPARE—not used.

Section V

Key Switch — OUT OF SERVICE—shows that the key switch is in the OFF position. This position electronically locks out the air start valve so that the GTM cannot be started or motored. This position also shows OUT OF SERVICE at the central control console.

NORMAL—shows that the key switch is in the ON position and the GTM is ready to operate, provided other external parameters are met.

Section VI

Start Counter GTM Timer — START COUNTER—registers a start each time $T_{5.4}$ is greater than 400 °F and N_{GG} is greater than 4300 rpm for 0.25 seconds.

GTM TIMER—shows running time for the GTM once the start counter requirements have been met.

Section VII

Manual Start This panel is used with Section XI, Start/Stop mode

VENT DAMPER OPEN/VENT DAMPER CLOSE—is a split level control/status pushbutton that controls the GTM cooling system vent damper.

COOLING FAN ON/COOLING FAN OFF—is a split level control/status pushbutton that controls the GTM cooling fan.

BLEED VALVE OPEN/BLEED VALVE CLOSE—is a split level control/status pushbutton that controls the GTM bleed valve.

STARTER AIR ON—is a control/status pushbutton that controls the air start valve.

IGNITER ON—is a control/status pushbutton that controls the igniters.

MAIN FUEL VALVE OPEN/MAIN FUEL VALVE CLOSE—is a split level control/status pushbutton. It controls both fuel valve No. 1 and No. 2 at the same time.

FUEL LOW TEMP OVRD—is a control/status pushbutton. It provides a logic override step that allows the GTM to be started, in manual initiate or auto initiate, with fuel temperatures below 80°F.

FUEL PURGE ON—is a control/status pushbutton. It allows cold fuel to be dumped from the GTM to the waste oil drain tank. This button is normally used when the module fuel temperature is below 80°F.

CLUTCH ENGAGE—is a control/status pushbutton that engages the GTM clutch.

CLUTCH DISENGAGE—is a control/status pushbutton that disengages the GTM clutch.

BRAKE ON—is a control/status pushbutton that applies the GTM PT brake.

BRAKE OFF—is a control/status pushbutton that releases the GTM PT brake.

COMPUTER TEST ON/PASS—is a split level control/status pushbutton. It starts a test of the torque computer and shows if the test was passed.

PT OVSP TRIP RESET—is a control/status pushbutton that resets the main fuel valves after an overspeed trip. NOTE: Do not depress this pushbutton until the engine comes to a complete stop.

VIB ANALYSER TEST ON—is a control/status pushbutton that tests the vibration analyzer circuits in the local control console.

Section VIII

Main Fuel Valve Check Switch(es)

No. 1—is a double position toggle switch that closes number 1 main fuel valve.

No. 2—is a double position toggle switch that closes number 2 main fuel valve.

Section IX

Control Transfer

ENABLE/INHIBIT—is a split level control/status pushbutton that enables the transfer of controls of the GTM controls to the central control console.

Section X

Emergency Controls (These controls are available at both consoles continuously)

FIRE SYS DISABLED/ PUSH TO RESTORE—is a split level control/status pushbutton. The top level alarms when there is a cooling system failure. A normal stop will also be started. Under this condition emergency trip switches are inoperative. If the cooling system is repaired, by activating the pushbutton you may then cancel the normal stop and the fire system is restored.

CO_2 RELEASE INHIBIT—is a control/status pushbutton that prevents the CO_2 fire system from releasing. You have 20 seconds to disable the CO_2 release after the module fire alarm occurs.

BATTLE OVRD ON—is a control/status pushbutton that prevents the following:

- GG High Vibration Trip
- PT High Vibration Trip
- GTM Cooling System Failure Trip
- PT Overtemperature Trip
- GTM Low Lube Oil Press Trip
- Fire Stop
- PT Torque Limiting in FSEE
- PT Speed Limiting in FSEE
- PT Acceleration Limiting in FSEE
- Fail-to-Idle Protection in FSEE

EMERGENCY STOP—is a double position toggle switch that provides an operator activated manual emergency stop. The associated alarm indicator alarms each time an emergency stop is activated. Emergency fuel trip switch activation will also generate an emergency stop alarm unless the cooling system failure exists or a normal stop is in progress (if in a normal stop, the trip valve closes, but no alarm is sounded).

Section XI

Stop

The stop half of the panel has five pushbuttons, three status indicators, and one alarm indicator. The pushbuttons are active only when the start/stop mode switch is in the manual initiate position.

INITIATE—is a pushbutton that starts a normal stop of the GTM.

CANCEL STOP—is a pushbutton that cancels a normal stop of the GTM.

FIRE STOP RESET, EMER STOP RESET, NORMAL STOP RESET—are logic circuitry reset pushbuttons for each of these sequences (active even in manual control mode).

INTERNAL FIRE—is an alarm that indicates an internal (post-shutdown) fire. If 3 minutes after shutdown $T_{5.4}$ is greater than 700 °F, the alarm will activate.

STOP INITIATED—is a status indicator that shows a stop has been initiated.

Stop—Continued

PLA AT IDLE—is a status indicator that shows when the PLA reaches idle. At idle a 5-minute cool-down timer begins.

FUEL VALVES CLOSED—is a status indicator that shows when the cool-down period is over. After cool down, the fuel valves close, which secures the GTM.

Start

The start half of the panel has two pushbuttons, a rotary select switch, two alarm indicators, and six status indicators. The two pushbuttons are active only in the manual initiate mode.

INITIATE—is a pushbutton that initiates a manual initiate start.

RESET—is a pushbutton that resets the logic circuitry for the manual initiate start sequence.

START/STOP MODE—is a rotary select switch that allows you to select the starting and stopping mode.

FALSE START—is an alarm that indicates one of two alarm conditions: (1) Less than 1200 N_{GG}, 20 seconds after the start air valve opens; (2) $T_{5.4}$ less 400 °F, 40 seconds after main fuel valves open (1200 N_{GG}).

ALIGN START AIR SYSTEM—is a status and an alarm indicator. As a status indicator, it comes on steady to show the air start system is being aligned for a start. As an alarm indicator, it comes on flashing to show the air start system will not properly align (either valves failed to properly position or anti-icing air is on).

START ALIGN COMPLETE—is a status indicator that illuminates after the logic circuits check alignment of the following:

- GTM in service
- Start air system aligned
- HP start priority check
- Fuel temperature
- Bleed air valve closed

PLA AT IDLE—indicates PLA AT 0%.

COOLING AIR SYS READY—shows the vent damper is open and the cooling fan is operating properly.

GG AT IGNITION SP—shows that GG speed is greater than 1200 rpm.

IGNITION—shows $T_{5.4}$ is greater than 400 °F.

START COMPLETE—shows GG speed is greater than 4300 rpm. (Once the start logic has been reset, electronically, the above status indicators extinguish.)

AIR/MAIN REDUCTION GEAR CONTROLS AND INDICATORS.—In the center of the console are the alarms for the air systems and the MRG/shafting. Also located in this section are controls and indicators for the intake system, and the starter, prairie, and masker air systems.

Figure 6-13 shows air controls, alarms, and MRG alarms. Refer to this figure as we describe the parameters for each indicator or control pushbutton.

A-1. SHAFT TORQUE HI (red). This alarm indicator is set to alarm at different set points for one engine operation (split plant) and two engine operation (full power). The split plant set point is 0.92×10^6 lb/ft (920,000). The full power set point is 1.5×10^6 lb/ft (1,500,000).

A-2. THRUST BRG TEMP HI (red). This is a summary alarm that monitors three thrust bearings. Two of the thrust bearings are in the two GTM clutch/brake assemblies. The third thrust bearing is the main thrust bearing on the MRG. The alarm set point is 165 °F.

A-3. JOURNAL BRG TEMP HI (red). This is a summary alarm that monitors all (26) MRG journal bearings. The alarm set point is 165 °F.

A-4. START AIR OVERTEMP (red). The signal for this alarm originates at an RTE in the start air system to the GTMs. The alarm set point is 450 °F.

A-5. Blank.

A-6. TURN GEAR ENGAGED (red). This status indicator shows when the MRG turning gear is engaged.

B-1. SHAFT SEAL PRESS LO (red). This alarm indicates when cooling/sealing water pressure to the propeller shaft seal drops below 12 psig.

B-2. SHAFT BRG TEMP HI (red). This alarm indicates when the temperature of the line shaft bearing(s) is above 180 °F. For the port shaft of DD-963 class ships this is a summary alarm. This means that any of the four bearings on that shaft can activate the alarm.

B-3. PRAIRIE AIR TEMP HI (red). This alarm indicates prairie air temperature above 100 °F.

B-4. MASKER AIR OVERTEMP (red). This alarm indicates masker air temperature above 200 °F.

B-5. BLEED PRESS LO (red). This alarm indicates bleed air pressure in the header is below 40 psig.

B-6. SHAFT LOCKED (red). This status indicator shows when the shaft lock mechanism is engaged at the MRG turning gear.

The next section we will discuss is the air control. Figure 6-13 shows three alarms for each main gas turbine and four alarms for each GTG. The air control alarms are at all propulsion consoles. This means that when an alarm occurs, it is displayed at each local control console and at the central control console.

The first set of main gas turbine alarms is for the intake ducting and anti-icing. The GTG alarms are identical except that an HP air alarm is added.

Air Control Alarms (Main Gas Turbine).— Descriptions of these alarms follow.

ICING (red)	This alarm is a combination of two parameters, temperature and humidity. These conditions are sensed by a detector mounted in the GTM enclosure barrier wall. The alarm set point is less than 41 °F and greater than 70% humidity.
ANTI-ICING INSUFFICIENT (red)	This alarm activates if anti-icing air is on and the intake air temperature is not greater than 36 °F. The sensor for this alarm is just below the anti-icing manifold in the intake.
DUCT PRESS LO (red)	This alarm activates if the pressure in the intake duct drops to 8 inches of H_2O vacuum.

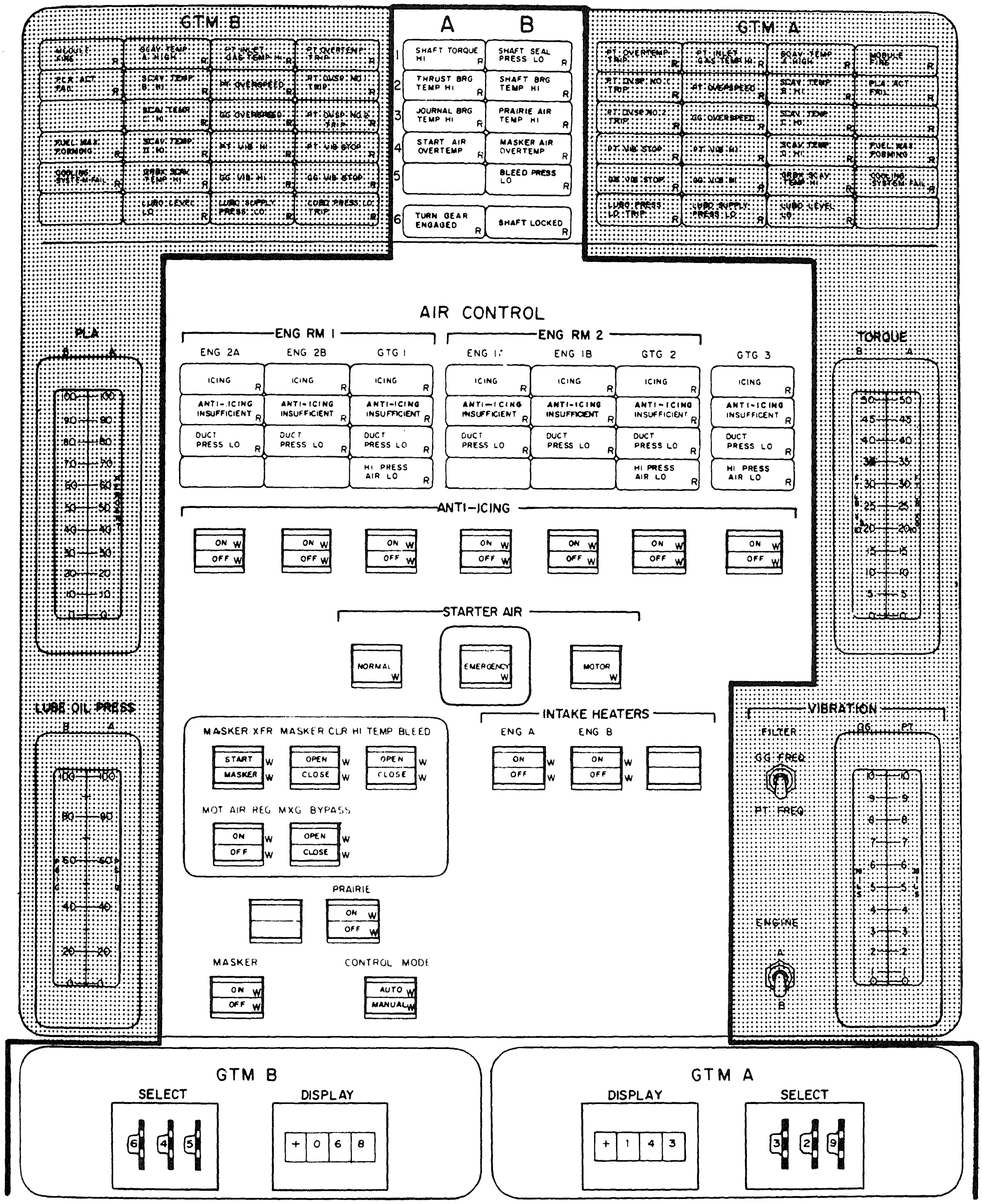

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Figure 6-13.—Air controls, alarms, and MRG alarms.

Air Control Alarms (Gas Turbine Generators).—Descriptions of these alarms follow.

ICING (red)	This alarm activates if the intake air to the GTG drops to 36 °F.
ANTI-ICING INSUFFICIENT (red)	This alarm activates if the intake air remains at 36 °F and the anti-icing system is on.
DUCT PRESS LO (red)	This alarm activates if the pressure in the intake duct drops to 8 inches of water.
HI PRESS AIR LO (red)	This alarm activates if the HP air bank pressure drops to 1000 psig.

The next section is anti-icing. This section is similar to the air control section. Like the air control section, you can turn on anti-icing bleed air for any running gas turbine at either PLCC or the PACC. The split level control/status anti-icing pushbuttons are all identical.

In the next section we will discuss the STARTER AIR pushbuttons. These three pushbuttons are used with the CONTROL MODE pushbutton at the bottom of the center panel. For the starter air pushbuttons to be active, the control mode button must be in the auto position.

Starter Air Pushbuttons.—Descriptions of these pushbuttons follow.

NORMAL	Selecting this pushbutton allows the logic, in the console, to align the bleed valves properly for a GTM start.
EMERGENCY	Selecting this pushbutton allows HP air to be available for a GTM start and high speed motoring in the event there is no bleed air and post-shutdown fire exists. NOTE: Some classes of ships do not have an HP air starting capability.
MOTOR	Selecting this pushbutton allows the logic in the control to align the bleed valves properly for a motoring cycle of the GTM.

After the starter air section are the control pushbuttons for each bleed air valve, prairie air, and masker air control.

The next section we will discuss is the INTAKE HEATERS pushbuttons. These split level control/status pushbuttons control the intake air heaters. These electric heaters are located on the louvers at the high hat intake. During cold weather, these heaters prevent ice formation on the intake. If the heater controller is in the remote position, the heaters will turn on when anti-icing is activated.

The last section of this panel is the demand display indicator (DDI). The DDI system is an operator information system. The system is used to verify parameters, check the system's operation, and to troubleshoot system malfunctions. Any parameter monitored can be displayed at any DDI location. The DDI system uses a three-digit address to probe the memory of the computer and find the value of the parameter. The DDI displays it in the display windows. To use the DDI system, you

1. determine the address for the required parameter;
2. dial the address in the SELECT thumbwheels; and
3. observe the value of the parameter in the display window.

In the DDI system the values are continually updated at the rate of four times a second.

CRP AND LUBE OIL SYSTEMS' CONTROLS AND INDICATORS.—The controls of the CRP and lube oil systems (figure 6-14) are located on the upper right panel of the console. The CRP section has one control pushbutton, one pressure meter, and six alarm indicators. The lube oil section has six control pushbuttons, one two-in-one meter and one liquid level meter, six alarm indicators, one rotary select switch, and one control transfer pushbutton. Also there is a small

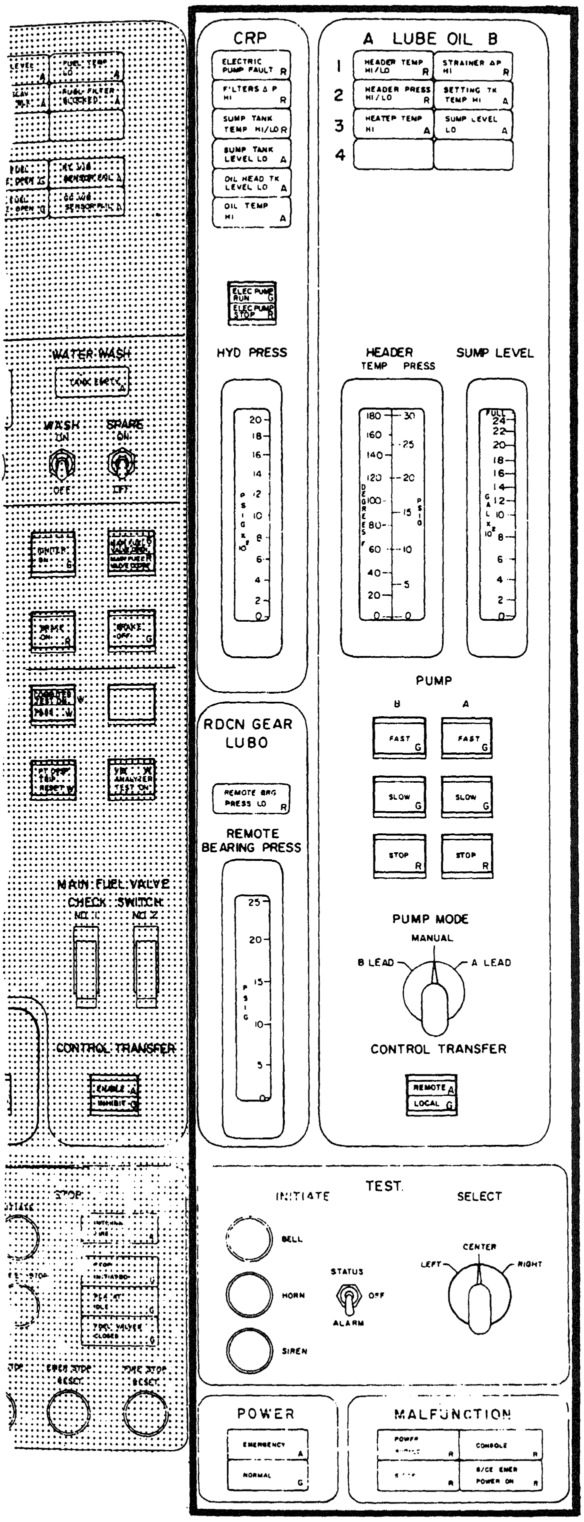

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Figure 6-14.—CRP and lube oil controls and alarms.

panel for the MRG remote bearing which has a pressure meter and an alarm indicator.

Refer to figure 6-14 as we discuss the CRP system first, the lube oil system second, and the remote bearing section last.

CRP Alarms and Indicators.—Descriptions of these alarms and indicators follow.

ELECTRIC PUMP FAULT (red)	The CRP pump must be running and pressure must be below 100 psig for more than 5 seconds.
FILTERS ΔP HI (red)	Summary alarm which monitors three sets of filters on the hydraulic oil pressure module (HOPM). There are two types of filters on the HOPM, two sets of 40 micron filters, and one set of 10 micron filters. The alarm set points are 40 psid (40 micron) and 70 psid (10 micron).
SUMP TANK TEMP HI/LO (red)	Hi 160 °F/Lo 60 °F.
SUMP TANK LEVEL LO (amber)	Less than 500 gallons.
OIL HEAD TK LEVEL LO (amber)	Low oil level in the CRP head tank. The set point is 10 gallons.
OIL TEMP HI (amber)	Oil temperature from the hydraulic pump to the system is greater than 180 °F.

The next indicator is the ELEC PUMP RUN/ELEC PUMP STOP split level control indicator pushbutton. This pushbutton controls the CRP electric hydraulic oil pump located on the HOPM. The only meter associated with the CRP is the hydraulic pressure meter in this section. The pressure shown is the HP oil at the output of the HOPM to the oil distribution box on the propeller shaft.

Lube Oil Alarms and Indicators.—Descriptions of these alarms and indicators follow.

A-1. HEADER TEMP HI/LO (red). Monitors the temperature of the MRG lube oil header. The set points are HI 130°F and LO 90°F. Inhibits clutch brake operation at 130°F unless the CCS key switch is enabled.

A-2. HEADER PRESS HI/LO (red). Monitors oil pressure in the MRG header. The set points are HI 27 psig and LO 15 psig. Inhibits clutch brake operation at 15 psig unless the CCS key switch is enabled.

A-3. HEATER TEMP HI (amber). Monitors the output temperature of the lube oil service system heater. The set point is 170°F.

A-4. Blank.

B-1. STRAINER ΔP HI (red). Monitors the MRG lube oil strainer differential pressure (ΔP). The set point is 10 psid.

B-2. SETTING TK TEMP HI (amber). Monitors the lube oil service system settling tank temperatures. The set point is 170°F.

B-3. SUMP LEVEL LO (amber). Monitors the lube oil level in the MRG. The set point is 1400 gallons.

B-4. Blank.

The HEADER TEMP/PRESS meter monitors the temperature and pressure of the lube oil at the MRG header. The temperature side reads in degrees Fahrenheit and the pressure side reads in pounds per square inch (gauge).

The SUMP LEVEL meter monitors the level of the MRG lube oil sump. The meter reads in gallons.

PUMP is a set of six control pushbuttons which control pump speed for both pumps.

PUMP MODE is a rotary select switch which allows for manual or automatic control of the lube oil pumps.

CONTROL TRANSFER is a pushbutton control switch. It transfers control of the lube oil system to the central control console.

Reduction Gear Alarm and Indicator.—RDCN GEAR LUBO is a small panel with an alarm indicator and a pressure meter. The parameters for this panel are sensed at the lower outboard first reduction gear bearing. The alarm indicator set point is 5 psig. The meter reads 0 to 25 psig. Because there is a certain amount of head pressure in the lube oil supplied to this bearing and its sensor, the meter tends to read 1 to 3 psig greater than lube oil header pressure.

Directly below the CRP, lube oil, and reduction gear panel is a small test panel. This panel is used to lamp test all the indicators and alarms on the local control console.

ENGINE ORDER TELEGRAPH (EOT) PANEL.—When the ship control console does not have throttle control, the officer of the deck must inform the station in control of speed requirements. This is done through EOT. The EOT is a communications system. It transmits propulsion command information between the station in command (ship control console [SCC]) and the station in control of the throttles (local control console or the central control console).

Figure 6-15 shows the EOT panel. The EOT panel has two major sections, the standard order pushbutton/status indicators and the digitized EOT. Operation and further explanation of the EOT panel will be covered later in this chapter under Propulsion Plant Operations.

The EOT panel also contains three alarm indicators, five status indicators, the ALARM ACKNOWLEDGE pushbuttons, a TORQUE SENSOR CUTOUT pushbutton, and a CONTROL TRANSFER pushbutton/status indicator.

TORQUE MISMATCH (red)	Indicates a mismatch of torque between the PT and the propulsion shaft. These values are electronically measured by the FSEE and the shaft torque sensor. The alarm set point is more than 25% difference of the two torque values for greater than 60 seconds.

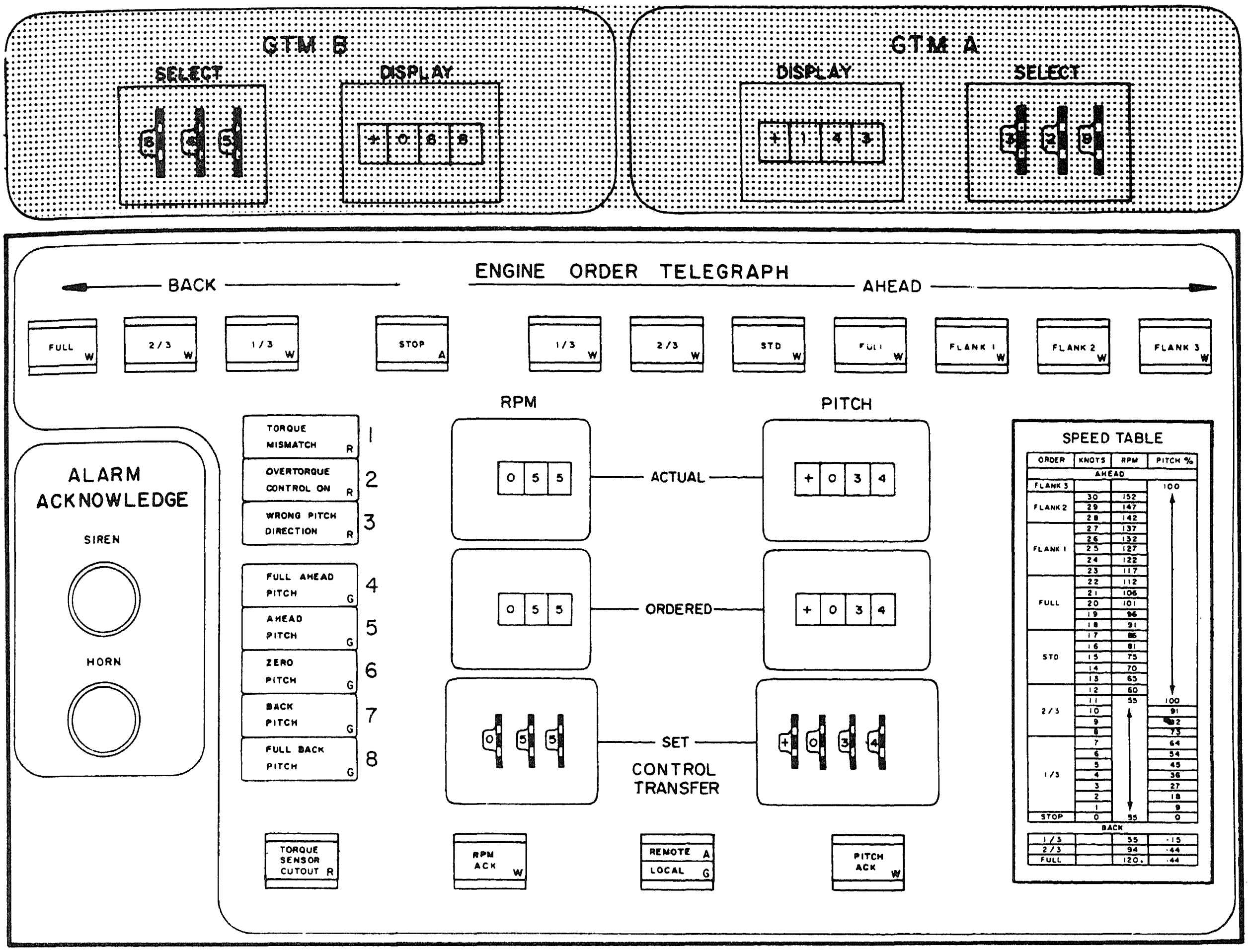

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Figure 6-15.—Engine order telegraph (EOT) panel.

OVERTORQUE CONTROL ON (red)	Indicates that overtorque control has been activated either in the FSEE (PT torque limiting) or by the console electronics (shaft torque limiting). This indicator illuminates when limiting is occurring. If after 20 seconds the overtorque condition still exists, the alarm will sound.
WRONG PITCH DIRECTION (red)	Indicates a difference between the commanded pitch, the position of the pitch control lever, and the actual pitch of the propeller. If the wrong direction condition exists for longer than 20 seconds, an audible alarm is sounded. If a wrong direction condition exists and shaft rpm is greater than 60, the console electronics will bring the PLA to idle.
FULL AHEAD PITCH (green)	Shows +100% propeller pitch.

AHEAD PITCH (green)	Shows +16% to +100% propeller pitch.
ZERO PITCH (green)	Shows −16% to +16% propeller pitch.
BACK PITCH (green)	Shows −16% to −49% propeller pitch.
FULL BACK PITCH (green)	Shows −49% propeller pitch.

The ALARM ACKNOWLEDGE pushbuttons are the main interface between you and the control console. Each time an alarm is activated, an audible alarm sounds. Amber (potential danger) alarms sound a horn and red (danger) alarms sound a siren. When any alarm activates, the proper procedures to follow are listed below.

1. Identify the alarm condition. The alarm indicator will come on flashing, and the audible will sound.

2. Acknowledge the alarm. Depress the proper alarm acknowledge pushbutton. This action silences the audible and causes the alarm indicator to glow steadily.

3. Investigate the alarmed condition following EOCC.

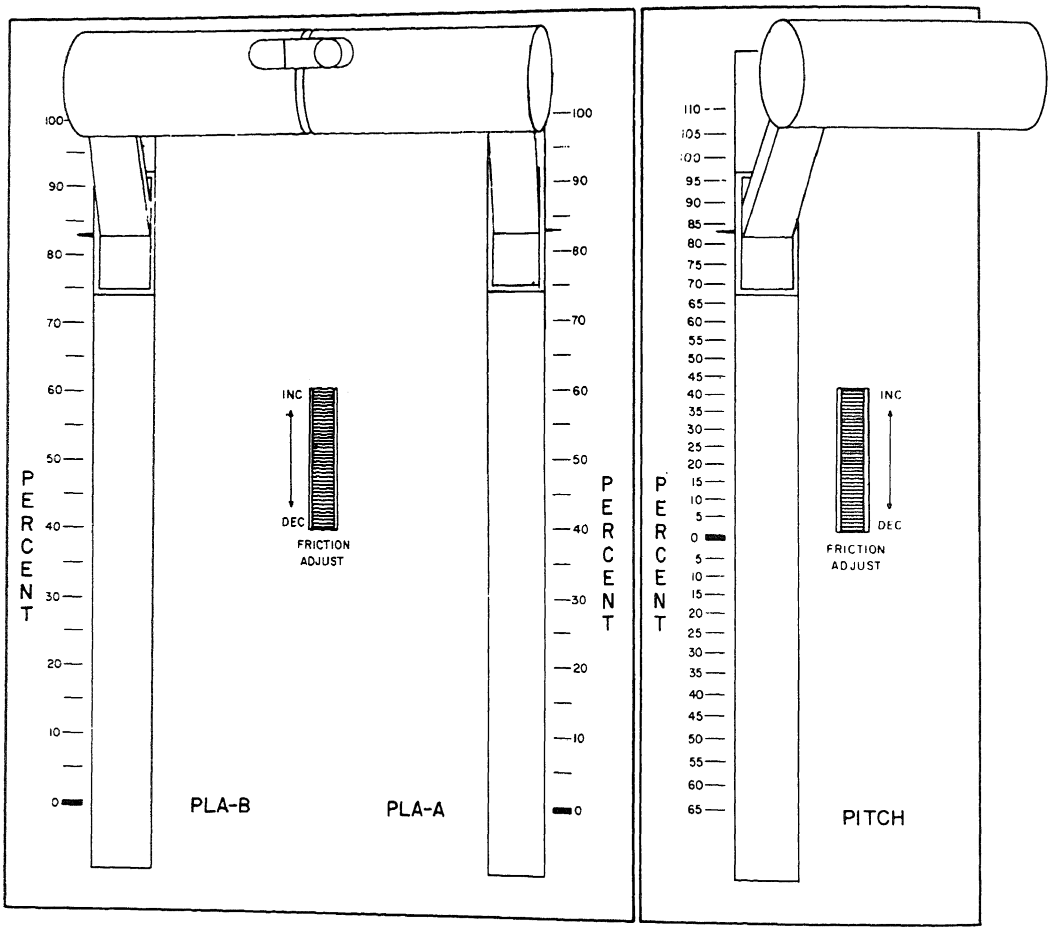

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Figure 6-16.—Throttle/pitch controls.

The TORQUE SENSOR CUTOUT is a pushbutton switch that electronically overrides shaft torque limiting. Shaft torque is sensed by a torsion meter installed on the propeller shaft. If propeller shaft torque becomes too great, an electronic signal is generated to limit PLA of the GTM. This action limits the power of the GTM until it is within normal power limits. When the torque sensor cutout is activated, propeller shaft torque is NOT electronically limited.

The CONTROL TRANSFER LOCAL/REMOTE pushbutton is the transfer button for the following functions.

1. GTM controls, start/stop functions
2. Clutch/brake controls
3. CRP pump control
4. EOT control

The control transfer button is used with the GTM ENABLE/INHIBIT pushbuttons discussed in GTM controls and indicators.

THROTTLE AND PITCH CONTROLS.— The throttle and pitch controls (figure 6-16) are levers which are electronically connected to the PLA of the GTM and to the CRP electronic enclosure, respectively. The throttle levers are graduated in percentage of PLA from 0% to 100% for each PLA. The pitch lever is graduated in percentage of pitch travel from 0% to 110% (ahead) and from 0% to −65% (astern).

Propulsion Local Control Electronics Enclosure (PLCEE)

The PLCEE contains electronics to convert the 120 volt a.c. to voltage levels used by the electronic and electrical components of PLOE. If the 120 volt a.c. input should fail, the PLCEE is automatically supplied by a 150 volt d.c. UPS system.

LM2500 OPERATION FROM THE LOCAL CONTROL CONSOLE

The following paragraph is a procedure for manually starting a gas turbine propulsion engine on a DD-963 class ship. You should use this procedure for training purposes only with this RTM. This procedure does not supersede the EOSS or any shipboard operating orders or instructions.

The local control console is capable of operating all equipment within the engine room associated with that console. As we have already mentioned, there are two modes of control available for starting and stopping a GTM: (1) manual control where you complete the steps to starting or stopping a GTM; (2) manual initiate control where you initiate the start or stop, and electronic logic completes the required steps. In the following section, we will present the steps and requirements for completing a manual start or stop.

SUPPORT SYSTEM ALIGNMENT

Perhaps the most vital step in preparing to start any GTE is the alignment of the support systems. You should use the EOSS to validate each auxiliary following the desired operating condition. You can align, validate, start, and then operate some support systems in an automatic condition. Other support systems you have to operate manually and monitor often. It is very important for you to have all operating support systems thoroughly validated and aligned before starting a GTE.

GTM MANUAL START SEQUENCE

A sequence of steps and events must take place at a specific time to start a GTE. If these events do not take place at their proper time, the GTE could malfunction or not start. Figure 6-17 is a start sequence flow diagram for a manual start; you should use this figure with figure 6-18, flow chart symbols.

Figure 6-17 shows seven steps at the beginning of the start sequence. These steps are preconditions that should be satisfied before the actual first step begins. An explanation of the seven steps, reading from left to right, follows.

Step 1—Align GTM support systems. All support systems must be aligned, validated, and operating normally.

Step 2—Align air start system. The air start system must be aligned, validated, and ready to operate in the selected mode.

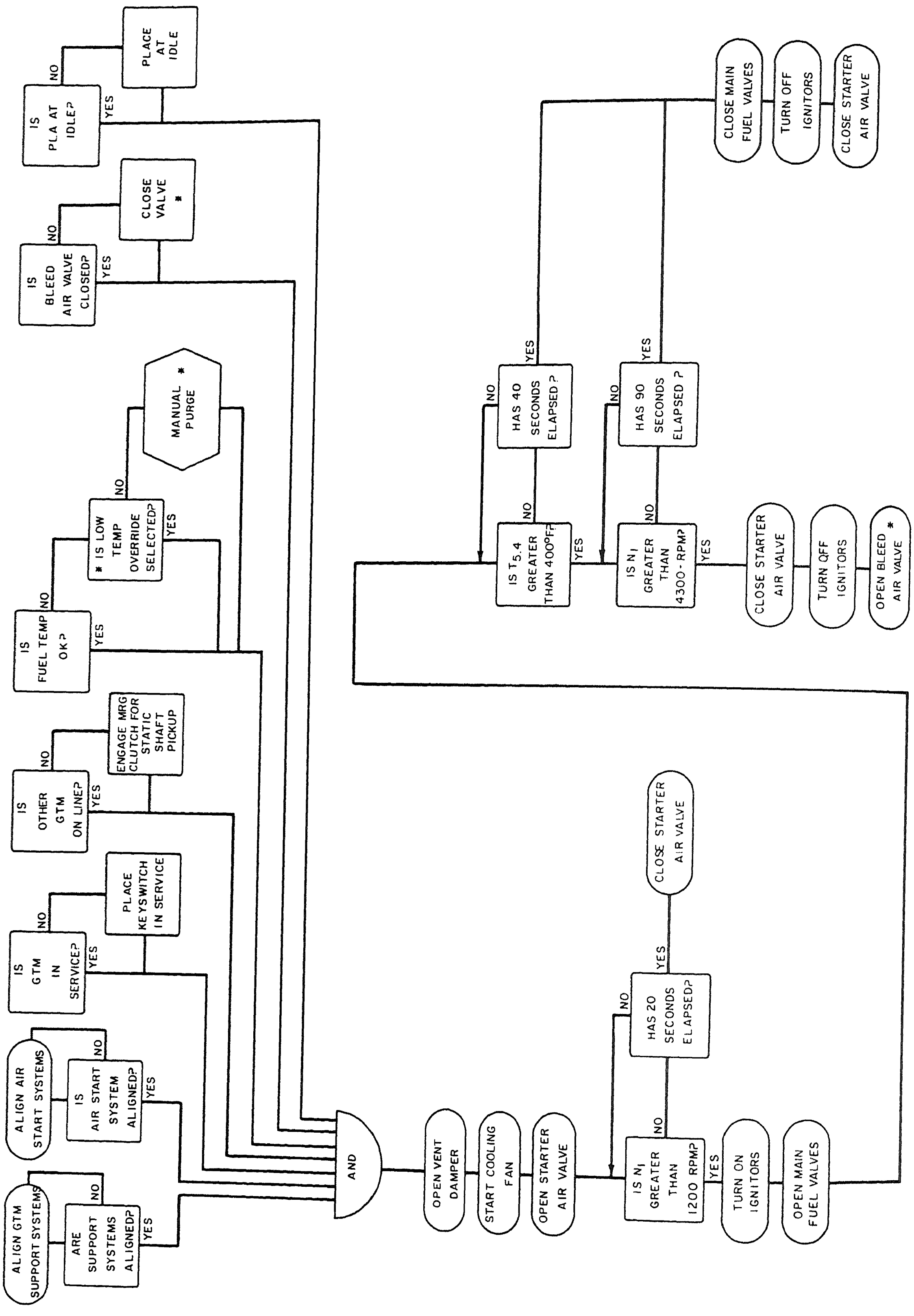

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Figure 6-17.—Manual start sequence flow diagram.

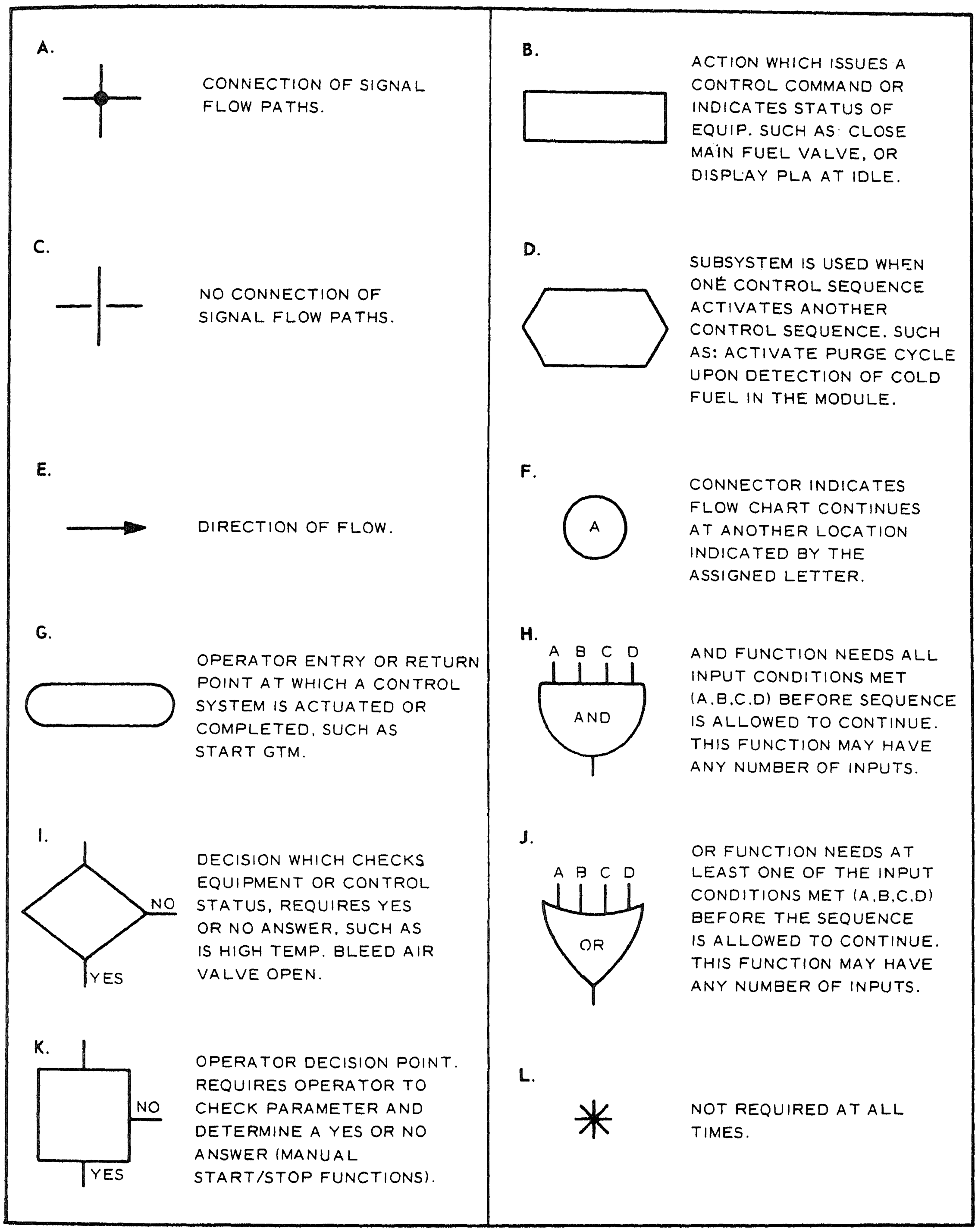

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Figure 6-18.—Flow chart symbols.

Step 3—Is the GTM in service? This decision point requires you to check the GTM key switch and place it in service.

Step 4—Is the other GTM on line? This decision point requires you to check the status of the other GTM in this engine room. If the other GTM is on line, no action is required. If the other engine is static, the GTM to be started must have its clutch engaged before start-up. The procedure is unique to DD-963 and DDG-993 class ships and is referred to as static shaft pickup.

Step 5—Is the fuel temperature OK? This decision point requires you to check the fuel temperature and determine if it is acceptable. If the fuel temperature is within limits, proceed to the next step. If the fuel temperature is too low, you are required to select fuel low temp override (as ordered by the EOOW) or perform a manual fuel purge cycle. (The manual purge cycle discards the cold fuel in the GTM. It replaces the cold fuel with hot fuel from the FO service system.) These are not required steps for an emergency start.

Step 6—Is the bleed air valve closed? This decision point requires you to verify the position of the bleed air valve and close it if necessary. This is not a required step for an emergency start.

Step 7—Is PLA at idle? This decision point requires you to ensure that the PLA is in the idle position.

Once all the preconditions have been met, you can begin the actual steps of starting the engine. The description of each of the steps of engine starting will follow, from top to bottom, the manual start sequence flow diagram (figure 6-17).

The first series of steps to start the GTM is the cooling air system. The first step is to open the vent damper and start the cooling air fan. Once this is done, you are ready for the actual starting. Remember, events must take place at a specific rpm and within a certain amount of time. If not, the engine will fail to start or malfunction.

The next step in starting the GTM is to open the starter air valve. At the same instant, you must also start a stopwatch or observe a clock to meet time requirements. Once the starter air valve is open, you should observe the GG speed meter for movement. As the meter rises, you can be sure you have GG rotation. When you have rotation, the next indication to check is the lube oil pressure meter. This meter should begin to move up as the GG speed increases above 500 rpm. If no oil pressure indication is present by the time the GG reaches 1100 rpm, close the starter air valve. Investigate the problem.

When the GG reaches 1200 rpm, the time frame is less than 20 seconds from 0 rpm. If the GG has not reached 1200 rpm within 20 seconds, close the starter air valve. Once the 1200 rpm window has been met, the igniters are turned on and the main fuel valves are opened. You must follow this sequence. If you reverse the steps, a hot start could occur.

Next, observe the temperature ($T_{5.4}$) window. $T_{5.4}$ must be greater than 400 °F in less than 40 seconds after the igniters are turned on and the main fuel valves opened. This shows you that the engine has "lit off." If this temperature window is not met, take the following actions.

- Close main fuel valves
- Turn off igniters
- Realign air system for motoring

You should take these actions in this order to prevent unburned fuel from remaining in the combustor.

Next, observe the speed window at 4300 rpm, GG speed. This window must be met in less than 90 seconds. This time frame is taken from the time the starter air valve is opened. If this speed window is not met, the action is the same as before.

- Close main fuel valves
- Turn off igniters
- Realign air system for motoring

Meeting the 4300 rpm speed window indicates that the engine is rotating freely and has attained greater than self-sustaining speed.

Your next actions are (1) close the starter air valve to secure starter operation; (2) turn off the igniters (they are no longer required because engine combustion is self-sustaining); and (3) open the bleed air valve, if required.

IDLE OPERATION CHECKS

Once the GTM is started, you must check a number of parameters to ensure the engine is operating properly. Generally, these idle checks are outlined in the EOSS. You should check all idle check parameters with the digital display indicators and the meters. Table 6-1 shows the parameters you should check and the observations you should make.

Table 6-1.—LM2500 Normal Idle Operating Parameters

Step No.		Parameter	Observation
A.		Assure that startup is completed.	N_{GG} 4900-5000 rpm
B.		Observe the following parameters:	
	1.	Lube Oil Pressure	16 to 30 psig NOTE Under certain lube oil temperature conditions you may operate the gas turbine with lube supply pressure below alarm level of 15 psig, but not below 6 psig.
	2.	PT Tempt ($T_{5.4}$)	1000°F max CAUTION If indication of compressor stall is encounter, perform emergency shutdown. NOTE A compressor stall at idle can be recognized by one or a combination of any of the following symptoms: higher than normal $T_{5.4}$, higher than normal fuel manifold pressure, or GG speed does not increase or is sluggish when throttle is advanced from idle position.
	3.	Fuel Manifold Press (FMP)	230-350 psig NOTE A minimum of 70 psig fuel manifold pressure is acceptable for 10 seconds maximum during deceleration to idle setting.
	4.	GG Speed (N_{GG})	4900-5000 rpm
	5.	Observe above parameter, $T_{5.4}$, FMP, and N_{GG}, together for indication of compressor stall.	Higher than normal $T_{5.4}$, higher than normal fuel manifold pressure, or GG speed does not increase or is sluggish when throttle is advanced from idle position.
	6.	(1) PT Speed (N_{PT}) (clutch and brake disengaged)	1600-2200 rpm
		(2) TACH Loss Indicators (N_{PT})	TACH Loss No. 1 and No. 2 lamps not illuminated

Table 6-1.—LM2500 Normal Idle Operating Parameters—Continued

Step No.	Parameter	Observation
7.	GG Vibration	4 mils max CAUTION Avoid extended operation at max vib limit. NOTE There are two vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibrations. A tracking filter for each pickup separates GG from PT vibrations depending on vibration frequency. Limits apply to frequency and not pickup location.
8.	PT Vibration	7 mils max
9.	Oil Tank Level	Visible in 19 gal sight glass NOTE The sight glass levels are based on usuable oil and are not the absolute levels of oil in the tank. Eight gallons are not usable. Usable range of oil in terms of absolute level is 8 to 32 gallons. This corresponds to 0 to 24 gallons of sight glass level. LUBO LEVEL LO alarm on at 8 gallons nominal absolute; LUBO LEVEL HI alarm at 40 gallons nominal absolute. Service oil tank if oil is not visible in 19-gallon sight glass.
10.	Lube Oil Heat Exchanger Outlet Temperature	135°-220°F max
11.	Scavenge Oil Temperature	200°-300°F normal all sumps (A, B, C, D) and gearbox, 340°F max
12.	Fuel Inlet Temperature	30° to 100°F max
13.	Fuel Filter Differential Pressure	7 psid max at idle. Alarm (FUEL FILTER BLOCKED) above 27 psid. Bypass opens at 35 psid, resets at 27 psid.
14.	Scavenge Filter Differential Pressure	5 psid max at idle. Alarm (LUBO SCAV FILTER BLK) above 20 psid
15.	Lube Supply Filter Differential Pressure	5 psid max at idle. Alarm (LUBO SUPPLY FILTER BLK) above 20 psid.
16.	Ventilation Exit Air Temp	Variable, 350°F max
17.	GG inlet Temp (T_2)	Approximately equal to outside air temperature (OAT)

:LUTCH ENGAGEMENT

Now that the GTM is running and the idle :hecks have been done, the engine is ready to be ngaged to the MRG and power train. The MRG cts as a coupler between the GTEs and the pro- eller shaft. This coupling or transmission link s done by the MRG. Basically, it has two main nputs and one main output. The two inputs are he PT couplings from each of the GTEs. The nain output is the ship's main propeller drive haft.

It is impractical for the main propeller shaft o turn at the same rpm as the GTE. So, there s about 21.5 to 1 gear reduction between the nput and the output drives.

The gearing is permanently attached to the ropeller drive shaft. Therefore, there must e a means of separating and/or connecting he PT shafts to the gearing. To make this onnection or separation, a clutch mechanism s provided for each PT shaft. When com- letely engaged, the clutch provides a direct onnection between the PT shaft and the main eduction gearing.

Each PT shaft also has its own brake system. The PT brake is a disk-type brake mechanism hat is physically attached to the PT shaft nd the MRG. The engaging or disengaging f either the brake or clutch is done at the ocal control console. If the PT brake is applied vhile the clutch is disengaged, it will stop the PT haft.

There are two different ways of engaging he clutch: (1) static shaft engagement or 2) dynamic shaft engagement. When both GTMs re secured or when one GTM is running but ot turning the propeller shaft, the static shaft ondition exists (static means not moving). For the static shaft engagement, the clutch must e engaged before starting the GTM. The reasons or this are very complex and will not be iscussed here. Remember, if the shaft is tatic, the clutch must be engaged before starting he GTM. Dynamic (moving) shaft clutch engage- nent can be done any time after the GTM has een started.

For proper clutch engagement, an initial condition must be set. That condition is PT brake ON, clutch DISENGAGED. To engage the clutch from this condition, only the CLUTCH ENGAGE pushbutton need be depressed. Logic automatically moves the PT brake off and then engages the clutch. In some cases, during dynamic clutch engage- ments, you may release the PT brake before engaging the clutch.

PROPULSION PLANT OPERATIONS

Before complete operation can begin, we need to discuss "breaking" the static shaft. During static shaft startup, the GTM was started and the clutch engaged. But generally the GTM will not produce enough net horse- power to start the shaft turning. Once you have completed idle checks, the throttle for the operating engine can be SLOWLY advanced to about 5 to 7 percent. You should maintain the throttle at this setting until the shaft starts turning. Then adjust the throttle to maintain the ordered shaft rpm. Sometimes the 5 to 7 percent throttle setting will not provide enough power to "break" the shaft. In this case, advance the throttle above 7 percent. Monitor N_1 closely. It should not exceed 7000 rpm. The throttle should never exceed 17 percent PLA without shaft rotation. If you advance the throttle to the 17 percent level and the shaft still does not turn, then secure the engine. If 17 percent PLA is exceeded with the shaft stopped, the engine will secure on an unidentified stop. Next, investigate the problem. Once the GTM is running properly and the clutch is engaged, operation of the propulsion plant (GTM(s), MRG, controllable pitch propeller) may begin.

NOTE: The motion and speed of the ship are directly dependent on the speed (rpm) of the shaft and the pitch of the propeller. The speed of the shaft generally remains constant to a given point on the speed table and then increases. The pitch of the propeller varies from 0 to +100 percent, or −49 percent, depending on the required speed.

Look at the relationship between rpm and pitch/speed (knots) in table 6-2. Note that shaft speed remains constant at 55 rpm through 11 knots and then begins to increase. Also, note that propeller pitch increases through 100 percent at the 11-knot speed. Commands for ship's speed are transmitted from the officer of the deck on the ship's bridge to the operating console by the EOT. There are two types of EOTs—the standard order EOT and the digitized EOT.

Table 6-2.—DD-963 RPM and Pitch/Speed Table

SPEED TABLE

ORDER	KNOTS	RPM	PITCH %
AHEAD			
FLANK 3			100
	30	152	
FLANK2	29	147	
	28	142	
	27	137	
	26	132	
FLANK 1	25	127	
	24	122	
	23	117	
	22	112	
	21	106	
FULL	20	101	
	19	96	
	18	91	
	17	86	
	16	81	
STD	15	75	
	14	70	
	13	65	
	12	60	
	11	55	100
2/3	10		91
	9		82
	8		73
	7		64
	6		54
	5		45
1/3	4		36
	3		27
	2		18
	1		9
STOP	0	55	0
BACK			
1/3		55	-15
2/3		94	-44
FULL		120	-44

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The standard order EOT consists of standard engine commands such as ahead 1/3, back 2/3, and ahead full. These commands are transmitted to the console on the standard order pushbutton/status indicators. When the order is transmitted, the appropriate pushbutton comes on flashing and the bell sounds. The order is acknowledged by depressing the flashing standard order pushbutton. This action silences the bell. You can then carry out the order by moving the throttle and/or pitch lever(s). Once the ordered speed has been met, the flashing indicator lights up steadily.

Digitized EOT provides digital RPM and PITCH commands in one-character increments. These commands are transmitted to the console on the ORDERED digital indicators on the EOT panel (figure 6-15). When the digital EOT is used, the bridge transmits the order. The RPM ACK and/or the PITCH ACK pushbutton(s) flash(es) and the bell(s) sound(s). Also, the ordered DDI changes to the new commanded speed and/or pitch. You move the SET thumbwheels to the position shown by the ORDERED DDIs. Then the order is acknowledged by depressing the RPM and/or PITCH ACK pushbutton(s). This action stops the indicator and silences the bell.

In the manual throttle mode, you have complete control of the shaft speed and the propeller pitch. To vary shaft speed, move the PLA throttle lever(s) while observing shaft speed (ACTUAL DDI) to maintain the ordered rpm. You can latch the two throttle levers together for two-engine operation or unlatch them for single-engine operation. To vary propeller pitch, you move the pitch lever to the desired setting. Propeller pitch settings respond rapidly and should move to the commanded position within 30 seconds.

You need much practice to move the throttle levers and pitch lever together to get the exact setting in the shortest time. Remember, when you operate this system, your goal is to answer the bells as fast and accurately as possible. Accuracy is the main consideration. Never let accuracy suffer just to be in a hurry. Also, remember that you always add pitch before power and remove power before pitch to prevent overspeed conditions.

During the routine course of operating the propulsion plant, you can expect numerous status, warning, and alarm indicators to come on. As each of these alarms happens, you must think of the possible problem areas and check these conditions. If the problem area is checked out promptly, there is a smaller chance of major damage to equipment. The accepted method of alarm investigation follows.

1. Note the alarm before acknowledging it. Sometimes, alarms will clear when they are acknowledged. These are known as transient alarms.
2. Acknowledge the alarm.
3. Verify the parameter using another means, such as DDI, meter, or gauge.
4. Go to the equipment and investigate the alarmed condition, if possible.
5. Report the condition of the equipment and the findings to the engineer officer of the watch in the central control station.

When assigned to a propulsion plant watch station during operations, you must be alert and aware of all conditions within the watch area. To be a good watch stander, you must be completely familiar with all the equipment and systems in the watch station. You should make frequent inspections of the watch station area. These inspections are to ensure that machinery is operating properly. They are to keep the operator informed of all operation conditions. Frequent tours of the watch station can alert the operator to abnormal conditions before they turn into major malfunctions.

SECURING THE PLANT

To stop a GTM under normal conditions, you must perform certain steps at specific times in the stop sequence. Refer to figure 6-19, manual stop sequence flow diagram, while following the text.

The first step after determining the engine(s) to be secured is to disengage the clutch. One of the clutch disengagement permissives is PLA at idle. So you must place the throttle at idle and then disengage the clutch. Once the clutch is disengaged, shut the bleed air valve.

When these pre-securing steps have been completed, leave the PLA at idle. Start a 5-minute timer. The 5 minutes provides a stabilization period for the GTM. During the 5-minute period, the engine cools down and all parameters stabilize. During the last 2 minutes of the cool down, check the parameters listed in table 6-3.

After you have checked those parameters and the 5-minute timer has expired, close the main fuel valves. As soon as the GG has coasted to a stop, place the PT brake on.

The next step is to start a 3-minute timer. When this timer expires, the temperature at $T_{5.4}$ should be less than 700 °F. If the temperature is less than 700 °F, the support systems can be secured, if required. If this GTM is to be placed in standby, most support systems should remain operating. If the temperature is greater than 700 °F, an internal (post-shutdown) fire is present. The accepted method of extinguishing an internal fire follows.

1. Trip the fuel emergency trip valve.
2. Shut the manual fuel supply valve.
3. Motor the gas turbine until $T_{5.4}$ drops below 400 °F.
4. Investigate the cause of the fire.

The first two steps in this procedure are to ensure that NO fuel is going to the GTM. The motoring step does two things—it blows the fire out and it provides cooling air for the internal parts. There are many causes of internal fires, but we will not discuss them here.

SUMMARY

Up to this point, we have discussed engine-room or local operation. As a GSE 3 or 2, you may be assigned watches at these watch stations. The material presented so far has given you a basic understanding of what operations may be done at the engine-room consoles. Remember, before you attempt any operation at these consoles, you must be familiar with and use the EOSS.

We will discuss central control station operations for Spruance class in chapter 9 and FFG-7 class in chapter 10. This chapter has only attempted to describe LM2500 operation at its lowest control point, the local operating station. Do not attempt LM2500 operation until you understand how the control stations operate. By the knowledge learned in this chapter, by using

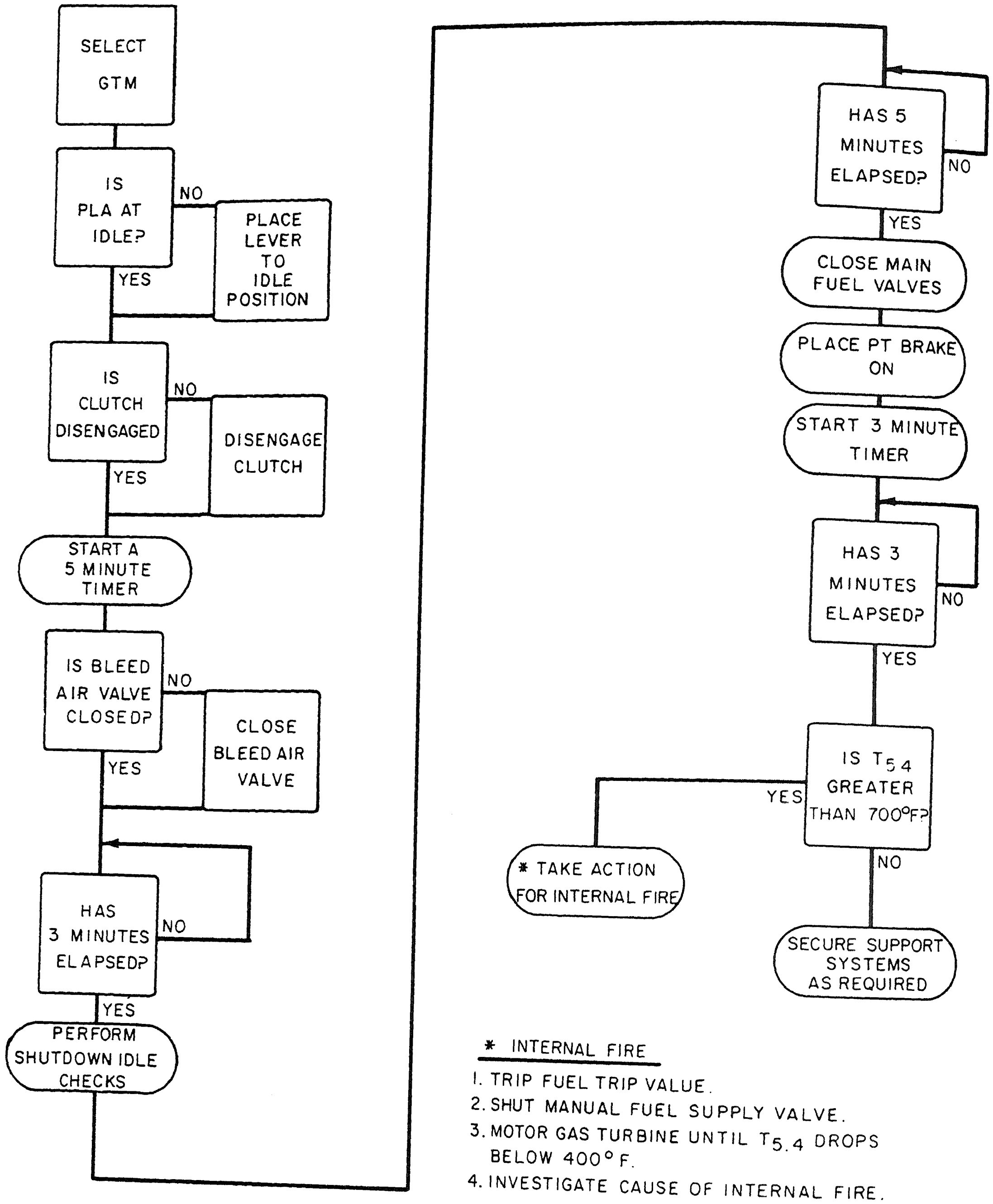

Figure 6-19.—Manual stop sequence flow diagram. 286.113

Table 6-3.—LM2500 Normal Shutdown Idle Checks

Parameter	Observation
A. Set gas turbine at idle power	PLA at idle discrete signal is generated
B. Operate gas turbine at idle power for 5 minutes. During the last 2 minutes observe the following parameters:	
1. Oil pressure	16 psig min
2. Fuel manifold pressure	230-350 psig max NOTE A minimum of 70 psig fuel manifold pressure is acceptable for 10 seconds maximum during deceleration to idle setting
3. N_{GG}	4900-5000
4. $T_{5.4}$ Temp	1000°F max
5. N_{PT} (clutch and brake disengaged)	1600-2200 rpm
6. GG Vibration	4 mils max NOTE There are two vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibrations. A tracking filter for each pickup separates GG from PT vibrations depending on vibration frequency. Limits apply to frequency and not pickup location
7. PT vibration	7 mil max
8. Lube oil heat exchanger	135°-220°F normal 250°F max
9. Scavenge oil temperature	200°-300°F normal 340°F max
10. Ventilation exit air temp	Variable, 350° max
11. Fuel filter differential pressure	7 psid max at idle. Alarm above 27 psid (bypass opens at 35 psid, resets at 27 psid)
12. Scavenger filter differential	5 psid max at idle. Alarm above 20 psid (bypass opens at 25 psid, resets at 20 psid)
13. Lube supply filter differential pressure	5 psid max at idle. Alarm above 20 psid (bypass opens at 25 psid, resets at 20 psid)
C. De-energize main fuel valves	$T_{5.4}$ drops below 400°F and N_{GG} and N_{PT} decelerates
D. Observe $T_{5.4}$ for 3 min after shutdown	700°F max

PQS and EOSS, and your experience under instruction watches, you should be able to readily qualify in your ship's engine-room watch station.

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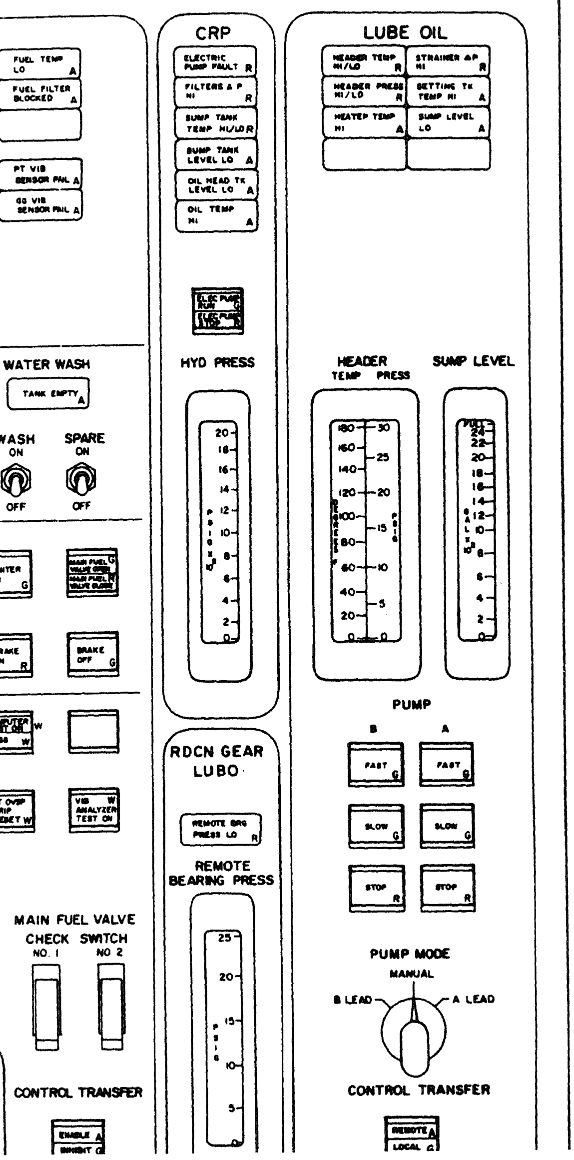
Propulsion Plant Manual, Propulsion Plant System for DD-963 Class Ships, Vol. 4, S9234-A1-GTP-040/DD-963 PPM, Chapter 27. Naval Sea Systems Command, Washington, D.C., 1 May 1980.

Study Guide Central Control Station Operators, Vol. 2, PE-18791-1 Rev 11-82. Diesel/Gas Turbine School, Service School Command Great Lakes, Ill., November 1982.



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CHAPTER 7

FREE STANDING ELECTRONIC ENCLOSURE

The free standing electronic enclosure (FSEE) is the major electrical interface to the LM2500 GT. As a GSE, you will perform many adjustments and checks on this very important piece of engine-room equipment. The FSEE controls the LM2500 electronically through many complicated circuits. It is also the connection point for the ship's propulsion consoles to input control commands and output parameters. Many of the circuits we will describe are used on all FSEE models. However, one section of the FSEE, the start/stop sequencer, is found only on the FFG-7 class ships. Each FSEE controls two LM2500 GTs, or in other words, there is one FSEE per gas turbine engine room. By properly maintaining the FSEE, you will ensure the LM2500 operates at peak performance levels, has available all its protective circuits, and can be relied upon for operation at any time. The FSEE is a fairly complex and sensitive unit. You should only attempt adjustments on it if you are thoroughly familiar with it. Therefore, you should work with a more experienced FSEE technician before making adjustments on your own. Then, only make adjustments following the LM2500 technical manual.

In this chapter we will cover the various circuits of the FSEE. By reading this and completing the associated NRCC, you should be able to understand the working of these circuits. We will also discuss how these circuits can change the engine's performance. Knowing this information will enable you to quickly diagnose FSEE malfunctions. We will also discuss the FSEE adjustments to give you a brief idea how to test and set these circuits. This chapter is ONLY a learning tool. It is not meant to and never should be used to replace the required technical manuals. You should use the required technical manuals when actually maintaining the FSEE.

Since the FSEEs are fairly identical on all classes of ships, we will discuss the basic FSEE, pointing out the differences as necessary. As mentioned earlier, the major difference is the use of the start/stop sequencer on the FFG-7 class. Another difference is the use of an acceleration limiting circuit in all classes but the FFG-7.

FSEE CONSTRUCTION

The FSEE (figure 7-1) is a solid-state unit mounted in a steel enclosure. Figure 7-1 shows an FFG-7 FSEE. It has two card racks (one per engine) and two power supplies. Each card rack has the control circuits for one engine. Fourteen circuit cards in each rack are used for GT operation. These are letter designated for reference and ease of identification.

Letter Designation	Name
A	PLA Actuator Board No. 1
B	Torque, Speed, and Acceleration
C	PLA Actuator Board No. 3
D (two per card rack)	Electronic Overspeed Control Switch
E	Signal Conditioner
F	Input/Output No. 1
H	Control

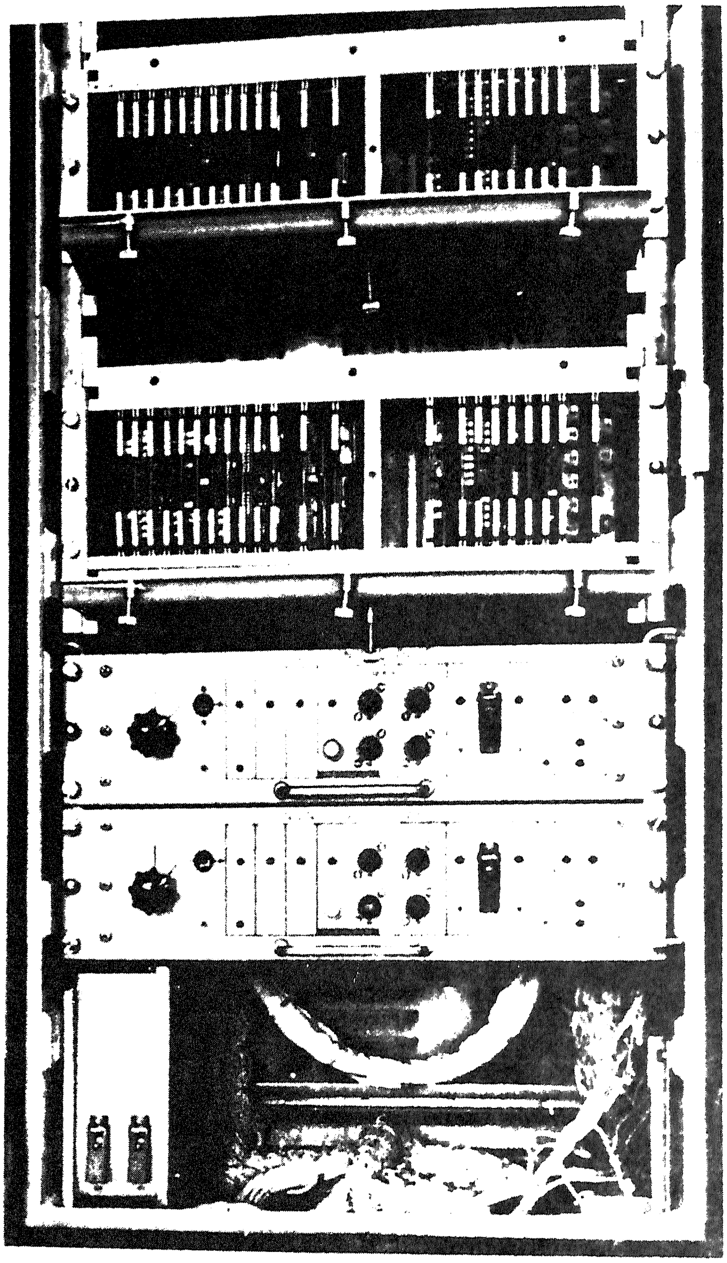

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Figure 7-1.—FFG-7 free standing electronic enclosure.

Letter Designation	Name
J	Arithmetic
K	Address Control
L	Memory
N	Input/Output No. 2
P	Sub Command
T	−12 and −15 volt d.c. power converter

The other nine circuit cards in each rack are used for the start/stop sequencer. These cards are:

Letter Designation	Name
X	Signal Conditioner No. 1
Y	Signal Conditioner No. 2
Z	Signal Conditioner No. 3
AB	Logic Card 1
AD	Logic Card 2
AE	Logic Card 3
AC	Logic Card 4
AA	Transmitter (10-volt d.c.)
V	Thermocouple Amplifier
	D. C. Converter 1ard No. 4

The FSEE also has two d.c. power distribution assemblies and an a.c. power distribution assembly.

The FSEEs used on the DD-963, DDG-993, and CG-47 class ships (figure 7-2) have fewer components. This is because the start/stop sequencing on these ships is done in the PLCC. Only one circuit card rack is used. It has the circuit cards for both GTs. One common card, the M card, is used by both GTs on these classes but is not used on FFG-7 FSEEs. The cards used in this FSEE are:

Letter Designation	Name
A (1 per GT)	PLA Actuator Board No. 1
B (1 per GT)	Torque, Speed, and Acceleration Limiter
C (1 per GT)	PLA Actuator Board No. 3
D (2 per GT)	Electronic Overspeed Control Switch
E (1 per GT)	Signal Conditioner
F (1 per GT)	Input/Output No. 1
H (1 per GT)	Control
J (1 per GT)	Arithmetic
K (1 per GT)	Address Control
L (1 per GT)	Memory
M (1 per FSEE)	Overspeed Indicator Pull-Up Resistor
N (1 per GT)	Input/Output No. 2
P (1 per GT)	Sub Command

This FSEE also has a dual redundant power supply set. It supplies power to the FSEE circuit cards and the engine. We will discuss this power supply in greater depth later in this chapter.

FSEE INPUT/OUTPUT SIGNALS

Because of the use of the start/stop sequencer, the FSEE on the FFG-7 has many more inputs and outputs than does the DD/DDG/CG FSEEs. Several inputs and outputs are the same for both FSEEs.

The FFG-7 FSEE uses 37 inputs per engine. These come from both the control consoles and LM2500. Many of these inputs are used by the

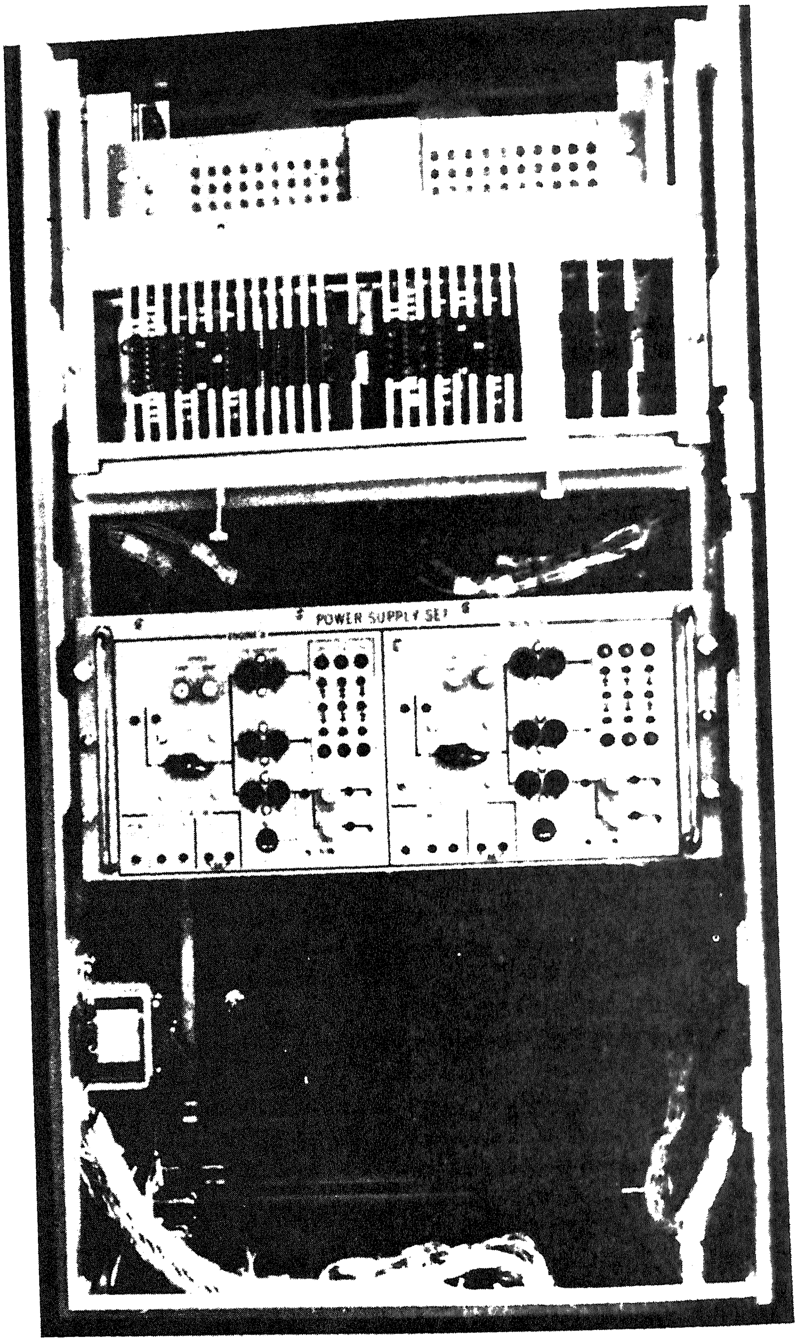

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Figure 7-2.—Free standing electronic enclosure found on DD-963, DDG-993, and CG-47 class ships.

start/stop sequencer for manual control of the engine. Some of the inputs are used to monitor engine operation. The remaining ones are used to control the engine. The main controlling outputs to the engine from the FSEE are PLA commands and fuel valve operation. The PLA actuator is the main interface between the FSEE control functions and the MFC. Signals from the FSEE set the PLA which, in turn, positions the MFC. The MFC is preset to schedule fuel at the proper level for each PLA setting. Varying the PLA setting will accelerate or decelerate the engine. Many inputs to the FSEE control this PLA setting to set the engine at its proper power level.

PLA OPERATION

The PLA actuator (figure 7-3) is an electromechanical motor actuator. It connects the FSEE's PLA electronics to the MFC. Its components have a d.c. torque motor, a line filter, a d.c. tachometer generator, a position feedback potentiometer, and a gear coupling.

The motor is driven by the PLA actuator drive signal from the FSEE. It supplies the torque needed to move the MFC lever at the proper rate. The direction the motor rotates is determined by the polarity of the d.c. voltage from the FSEE. The velocity of the motor is proportional to the amplitude (strength) of the drive signal. The motor is connected to the output drive lever by a four-gear drive train that steps down motor speed and increases torque.

The input voltage range is between 0 to ± 23 volts d.c. This will turn the motor between 0 and 900 rpm which, when stepped down through the gear train, equals about 0 to 16 rpm. The MFC lever will be at steady state only when the input signal is 0 volts d.c. The PLA actuator is capable of turning 15 rpm, or 90 degrees per second, clockwise or counterclockwise with a ± 23-volt d.c. input signal. PLA rate limit circuits, discussed later, limit the rate increase to 2.1 volts per second in the increasing direction and 9 volts per second in the decreasing direction. This limits the PLA actuator movement to 8.2 degrees per second increasing and 73.9 degrees per second decreasing. The motor can run into external hard stops and remain stalled at full voltage without damage. The input signal is filtered by an RFI

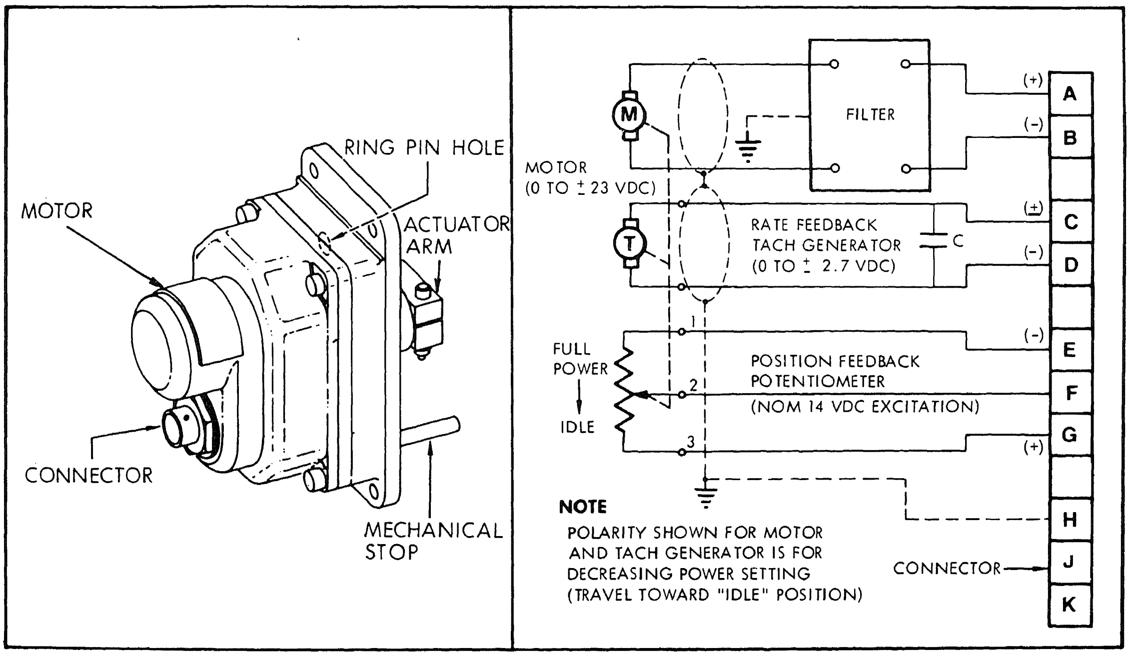

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Figure 7-3.—Power lever angle actuator.

input filter. The filter reduces the possibility of external electrical interference from affecting the PLA input signal.

The PLA actuator also incorporates two feedback circuits that input the FSEE. These are used to tell the FSEE the position and the rate of travel of the PLA actuator.

The rate of travel is measured by a tachometer generator. This is a d.c. generator that is directly coupled to the PLA motor shaft. This generator outputs a d.c. voltage proportional to motor speed which is also proportional to the output shaft speed. The polarity of this voltage depends on the direction the motor shaft turns. The range of the output of the generator voltage is 0 to ± 2.7 volts d.c. for output shaft speed of 0 to 15 rpm. The signal is sent to the FSEE. It is commonly called rate feedback.

The other feedback signal is used to tell the FSEE the position of the PLA actuator output shaft. This signal originates from a linear nonwire-wound variable resistor. The pot slider position of the resistor is controlled by the actuator output shaft. Since the PLA actuator output lever only moves about 100 degrees, the potentiometer is driven by a set of gears to increase its accuracy. The potentiometer is allowed to move about 227 degrees. A reference voltage of 14 volts d.c. (nominal) is applied to each end of the potentiometer. The feedback signal is taken from the sliding arm. This voltage divider action is proportional to the position of the PLA output shaft.

The PLA is physically mounted on the engine's fuel pump. The output lever is connected to the MFC power lever. Rig features allow locking of the PLA actuator output lever at a position of 113.5 ± 1 degree. This is used when setting the linkage between the PLA actuator and the MFC. Rigging of the PLA is also done electrically and should be done following the manufacturer's technical instructions.

PLA ACTUATOR ELECTRONICS

The PLA actuator circuits are used to control the MFC within predetermined safe limits. The PLA electronics has 13 control, detection, and monitoring functions. These PLA circuits are found on three circuit cards in the FSEE (the A, B, and C cards) and associated circuitry in the d.c. power distribution assemblies.

In the following paragraphs we will discuss the PLA circuit. Figure 7-4 (a foldout at the end of this chapter) is a block diagram of the PLA circuit. The components we will discuss are keyed by parenthetical numbers to the figures. To make the description and explanation easier for you to understand, the PLA circuit is subsectioned into 14 illustrations (figures 7-5 through 7-18). Please follow these figures as we discuss the various components.

Potentiometer Slider Control

The main purpose of the potentiometer (or pot) slider control is to provide the FSEE with feedback from the PLA actuator as to its position. (Since it is interlocked to the MFC, it also gives feedback to the MFC's position.) This signal is compared to the command rate limited signal in an error detector (summation amplifier No. 1) for determining the difference between the actual PLA position and the commanded position. The pot slider control also provides uplink (out to the propulsion consoles) of the actuator position and signals that are used in the C card (PLA actuator card No. 3).

The pot slider signal (figure 7-5) is a d.c. position feedback signal from the variable pot in the PLA actuator (1). This signal is proportional to the MFC lever position. It represents the lever position from zero to full power. This signal is sent to a unity gain isolation amplifier (2). This provides for a high impedance load for the variable pot. Figure 7-5 shows the PLA servo loop block diagram. Notice where position feedback is sent to the junction at error detector No. 1 (3). The uplink signal is conditioned by a lever shifter/driver (4). The lever shifter/driver changes the uplink signal to a low output impedance signal. This signal is capable of driving the circuits in the propulsion consoles.

The pot slider signal represents minimum (idle) to maximum (full power) MFC positions. This signal is sent to the idle position detector (5) (to output PLA at idle signals). It is then compared to a reference signal. This sets the threshold of the detector to a point 2 degrees above the idle position. If the MFC lever position is below this

threshold, the idle position detector operates a relay (6) in the power distribution assembly. The relay outputs the PLA at idle signal. If the lever is above this position, the detector has no output. This opens the relay and removes the PLA at idle signal.

Command Control

The position of the MFC lever is controlled through the PLA actuator by the command signal (figure 7-6). The command rate limiter limits the rate of change of the lever.

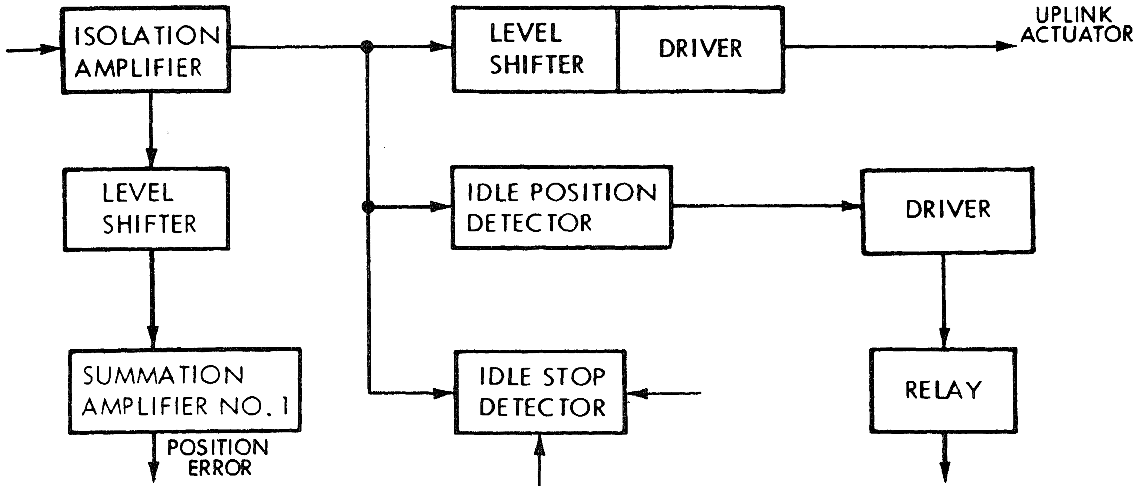

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Figure 7-5.—Potentiometer slider circuit.

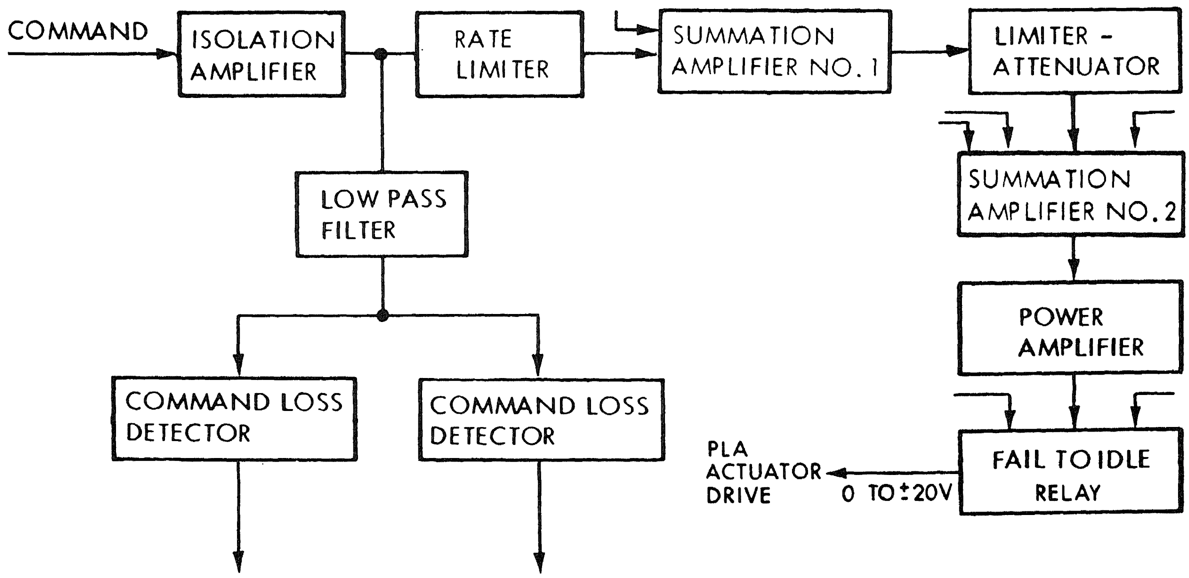

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Figure 7-6.—PLA command control

It limits it to preset increasing and decreasing rates.

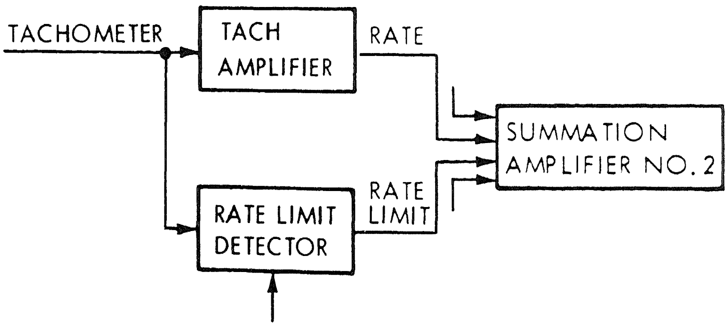
The command signal (7) enters the FSEE and is sent to a unity gain isolation amplifier (8). This provides a high impedance load for the d.c. voltage of the command signal. The rate limiter (9) is used to limit the rate of change of command. The output of the rate limiter is sent to the summation amplifier (3). There it is summed with the position feedback signal. These two signals are of opposite polarity. The output of the amplifier is the position error (the difference in the position of the MFC lever and the command rate limit signal). This signal is applied to the limiter/attenuator (10). Under normal conditions it allows the signal to pass to the summation amplifier No. 2 (11) unchanged. The function of the limiter/attenuator will be discussed under the section on torque control. The output of summation amplifier No. 2 is sent to the power amplifier (12) in the power distribution assembly. It is then sent through the fail to idle relay (13) and used to drive the PLA actuator.

Tachometer Control

The tachometer (tach) control (figure 7-7) provides the rate of change feedback to control the response of the PLA actuator during MFC lever changes. This circuit is used to keep the lever from excessively overshooting the desired PLA position during changes. The tach control is also used during special cases for rate limiting during torque limiting. This is done when the command rate limiter is not used to control the rate of change of the PLA actuator.

The tach signal (14) is applied to two circuits on the A card. These are the tach amplifier (15) and the rate limit detector (16). The tach signal is a d.c. voltage signal proportional to the rate of change of the MFC lever. The signal is zero when there is no rate of change. The signal polarity will vary depending on the direction of movement of the PLA actuator. This signal is amplified in the tach amplifier (15) and sent to the summation amplifier No. 2 (11). Normally the signal is summed with the position error signal from the limiter-attenuator (10). The tach signal is subtracted from the position error signal during change of lever position. This reduces the signal output from the summation amplifier No. 2 (11). Since the signal to the PLA actuator is reduced, it tends to slow down. As the lever approaches the command position, the difference between the command signal and the position feedback is reduced. The tach signal then has greater control in slowing down the lever and reducing overshooting. When the command position is reached, the tach signal and the rate signal are both returned to zero.

The tach signal is also sent to the rate limit detector (16). There it is compared to a reference signal limit (V_{ref}). The V_{ref} represents the maximum limit for the rate of changes for the MFC lever. It does this in the increasing direction only. The output of the detector is the rate limit signal, when the input exceeds the reference limit. This rate limit signal is proportional to the amount the input exceeds V_{ref}.



293.52.3

Figure 7-7.—Tachometer feedback circuit.

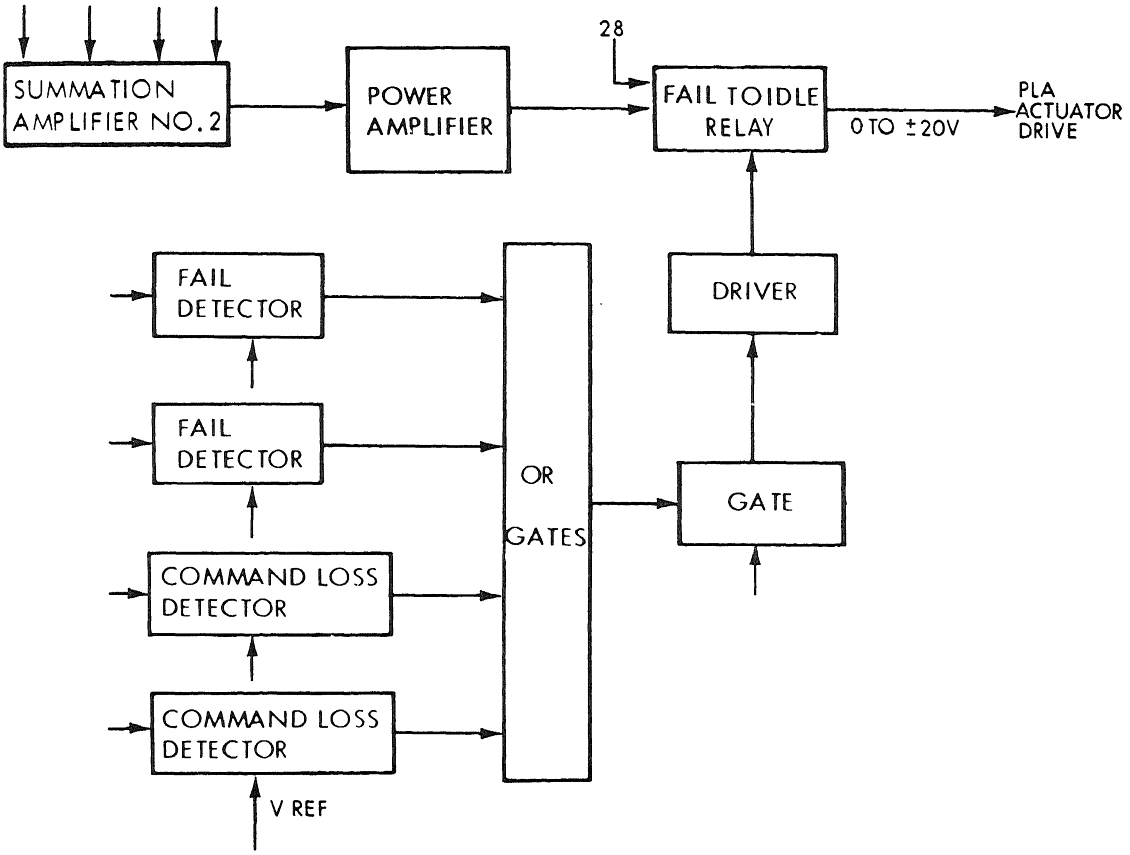
The rate limit signal is sent to the summation amplifier No. 2 (11). There it is summed with the position signal and the rate signal. The rate limit signal is the same polarity (except for much greater amplitude) as the rate signal. This, then, tends to retard increases in the lever position. Because the rate limit signal is stronger, it has more effect in retarding the rate of change (only in increasing directions). It actually limits the rate of change to a point just a little higher than the limit set by V_{ref}.

The special case we discussed earlier involves limiting that may be specially required. This is when the PLA actuator is coming out of an over-torque condition and the MFC lever is returning to its command position. In this case, a large position error exists. This is because the command position and actual PLA position are out of line as a result of torque limiting. Because of this large error, the MFC lever would be driven to its new position at an excessive rate. The rate limiting circuit limits the actuator travel and allows a slower PLA response.

PLA Actuator Drive

The PLA actuator drive (figure 7-8) provides the power to drive the actuator motor. It also provides the fail to idle signal that drives the motor during FSEE malfunctions.

In normal operation, the output of the summation amplifier No. 2 (11) is amplified by the power amplifier (12) in the power distribution assembly. The output of this amplifier is sent through the fail to idle relay (13). This signal, in turn, is sent to the PLA actuator. A fail to idle signal is sent to the relay from either the fail or



293.52.4

Figure 7-8.—PLA drive and fail to idle circuit.

command loss detector (discussed later in this chapter). If this occurs, the amplifier output is disconnected by the gate (17); a 28-volt d.c. signal is inserted to drive the motor. The polarity of this signal is such that it drives the PLA to the idle stop.

Torque Control

Torque control (figure 7-9) provides torque limiting of the gas turbine. This is used when the engine torque exceeds the torque level set point. The torque control circuit may either restrict the advance or decrease the setting of the PLA.

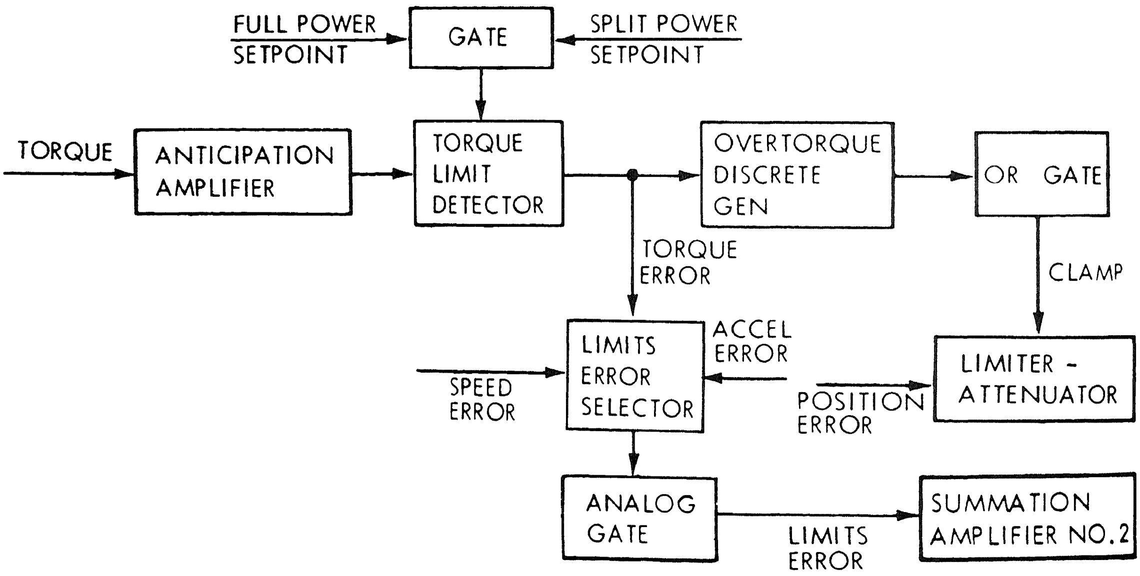
The torque signal from the torque computer (19) (discussed later in this chapter) is amplified by the anticipation amplifier (20). This amplified signal is sent to the torque limit detector (21). There it is compared with either the full-power or split-plant set point from the gate (22). When the engine torque is above the torque limit set point, the detector outputs a signal proportional to the amount that the torque signal exceeds the limit (torque error). When this happens, the overtorque discrete generator (23) sends out a discrete signal. This signal indicates that an overtorque condition exists. This discrete signal is also sent to the limiter-attenuator (10) via an OR gate (24). This signal puts the limiter-attenuator into the mode where the position error is lessened and limited by the limiter-attenuator.

The torque error signal is also sent to the limits error selector (25). Applied to the selector are speed error and acceleration error signals. The selector outputs the largest of these three signals. This output is applied to the summation amplifier No. 2 (11) via a normally closed analog gate (26).

During an overtorque condition, the amplitude and polarity of the torque error signal are enough to overcome the other signals that input the summation amplifier No. 2. This then becomes the controlling signal used to drive the PLA. It sets the PLA at a lower setting limiting PT torque.

When the torque signal is below the torque limit set point, the output of the torque limit detector is zero. This allows the overtorque discrete generator to send out a below torque limit signal to the gate that controls the limiter-attenuator. This then allows the limiter-attenuator to pass through the position error signal without either limiting or attenuating.

The response of the torque limiting system to changes in torque is controlled by the torque anticipation amplifier. The output of this amplifier is approximately proportioned to steady state speed plus rate of torque change times a



293.52.5

Figure 7-9.—Torque control.

constant. During steady state conditions, the amplifier has a gain of 2. During changes in torque, the amplifier anticipates these changes by adding an output signal component. This output is proportional to the rate of change. During rapid increase in torque, the anticipation circuit causes the torque limit set point to be reached earlier without the amplifier. The torque signal drives the MFC lever earlier in anticipation of an overtorque condition. This reduces the possibility of overshooting the torque set point.

OVERTORQUE MONITORING.—The FSEE outputs an overtorque condition uplink signal to the propulsion consoles when the overtorque occurs. Figure 7-10 shows the overtorque discrete signal circuit. The output of the torque limit detector (21) is converted to the overtorque discrete signal in the overtorque discrete generator (23). This output, in addition to the uses previously discussed, is sent to a gate (27). The gate selects either the test passed output or the overtorque output. The test passed output is only selected by the gate when the torque computer is put into a test. The selected gate output is sent to one of two drivers (28 or 29) to provide the uplink signals.

SET POINT MODE CONTROL.—The FSEE must select to which of the two set points to limit the engine torque. This is done by the set point mode control. The mode is selected by a discrete signal that tells the mode control whether one or two gas turbines are on line. Figure 7-11

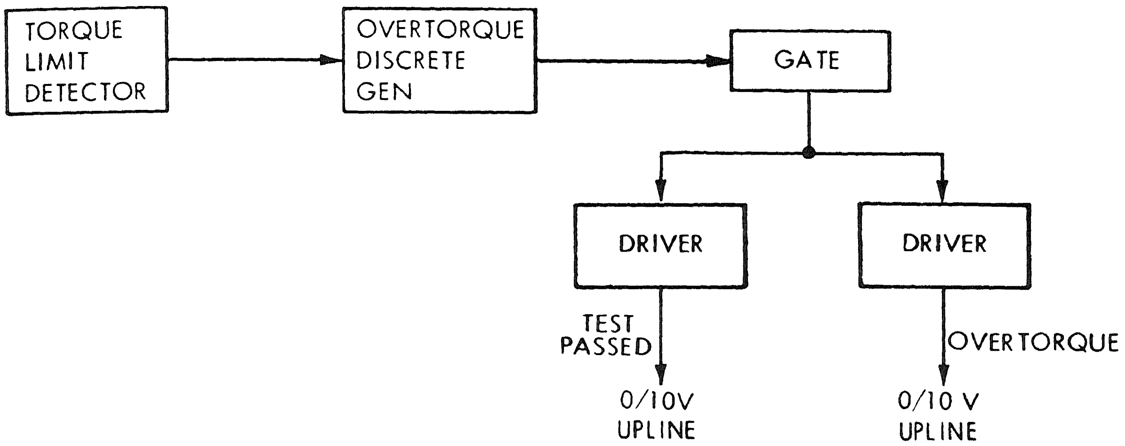


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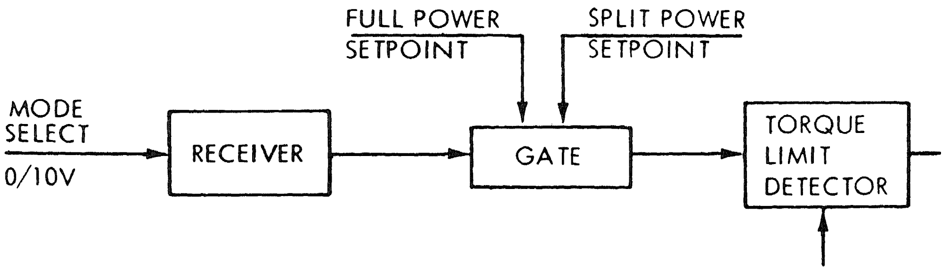
Figure 7-10.—Overtorque discrete signal.



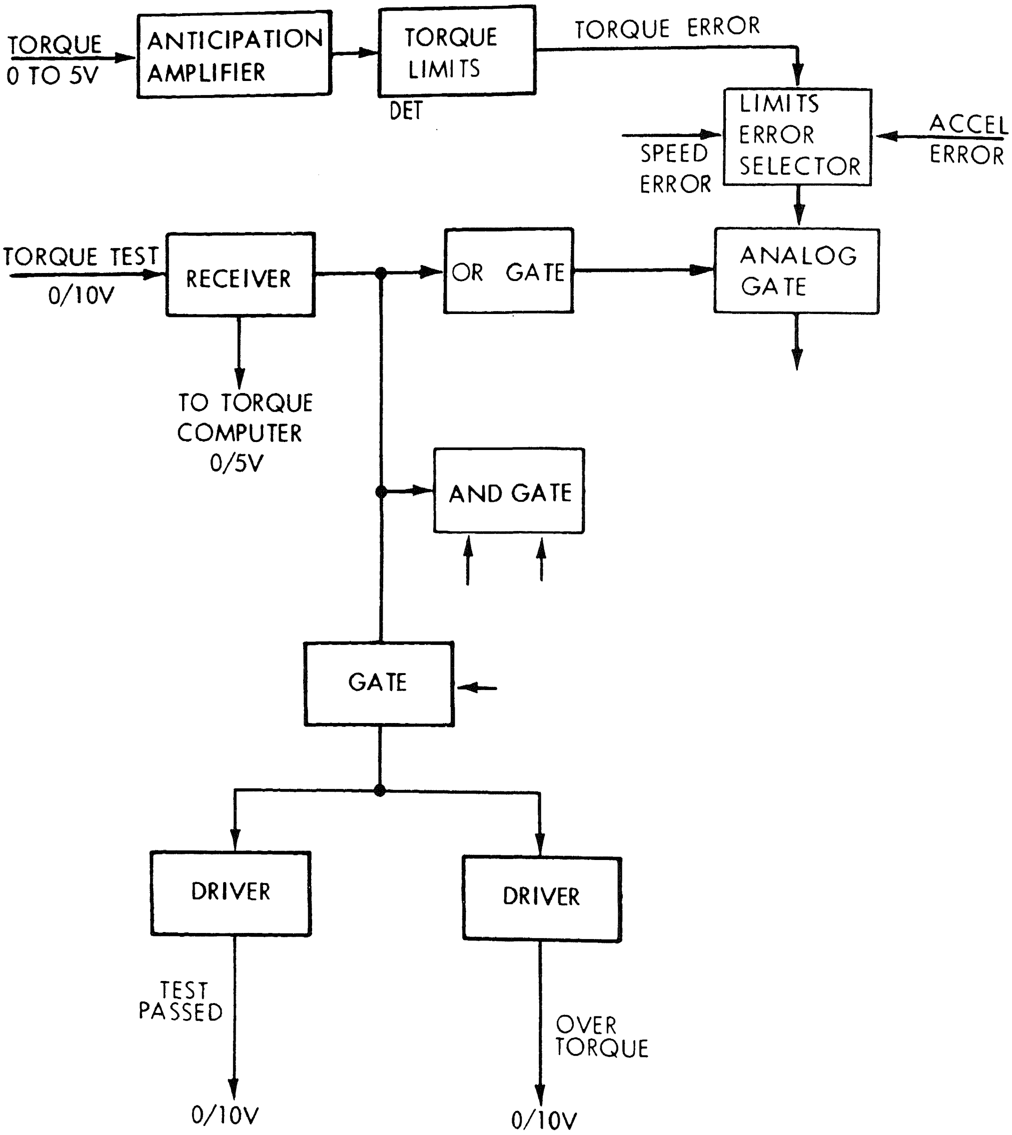
293.52.7

Figure 7-11.—Torque setpoint detection.

shows the torque set point detection circuit. The input signal (30) is converted to a logic level signal in a receiver. The output of the receiver is used to control a logic gate (22). It selects either the split-plant (one GT) or full-power set points (both GTs) as the threshold for the torque limit detector (21). You can manually adjust each of the set point sources to calibrate the torque limiting level.

TORQUE COMPUTER TEST.—When the torque computer is tested, the torque loop is opened. Then a test torque signal is applied from the torque computer. This tests the torque computer and the torque limiting circuits. A discrete signal is generated and sent out to indicate the status of the test.

The torque testing circuit is shown in figure 7-12. The torque computer test signal (31) is conditioned to a standard logic level by a receiver (32). This signal performs three functions. First it is sent out to the torque computer (33) and causes a test torque signal to be generated. This test signal



293.52.8

Figure 7-12.—Torque testing.

is sent to the input of the torque limiting circuit (19) with a high enough amplitude to exceed the torque set point. Second, the output of the receiver (32) is sent to the analog gate (26) at the output of the limits error selector (25) via an OR gate (34). The analog gate is opened. It prevents the torque error signal from affecting the MFC lever when a torque computer test is done. CAUTION: Do not conduct the torque computer test in FSEE while the GTM is running. Third, the test signal also inhibits the overtorque driver (29) and enables the test passed driver (28) via the gate (27). This causes the torque error signal to be passed uplink as test passed. If a circuit malfunction causes the test signal to be below the set point level, the test passed output would be zero. The torque computer signal is also sent to a three-input AND gate and will be discussed in system fail monitor.

Speed Control

The speed control function of the FSEE limits the PT speed if it attempts to exceed preset limit. Figure 7-13 shows the speed control circuit. The PT speed signal (35) is a voltage proportional to the PT speed. (Refer to chapter 3 for an explanation on the development of this signal.) The signal is sent to a signal conditioner (36). Then it is sent to the speed anticipation amplifier (37) where it is directed to the speed limit detector (38). In the speed limit detector, the signal is compared with a preset speed limit signal.

The output of the anticipation amplifier (37) is proportional to the steady state input speed signal plus the rate of speed change times a constant. Therefore, when engine speed is constant, the anticipation amplifier acts as a normal unity gain amplifier. When speed changes occur, the output anticipates these changes by adding an output signal component. This output signal is proportional to the rate of the speed change. Thus, the preset limit can be exceeded earlier in time than would be the case without the anticipation amplifier. When the PT speed exceeds the limit, the speed limit detector outputs a speed error signal. This speed error signal is proportional to the amount that the speed input signal exceeds the limit. When the limit is exceeded, a signal is sent to the speed limit discrete generator (39). The generator outputs a discrete signal that indicates speed limiting is in effect. This discrete signal is sent to the limiter-attenuator (10) via the OR gate (24). This puts the limiter-attenuator into the mode where the position error signal is either limited or attenuated. This is similar to torque control.

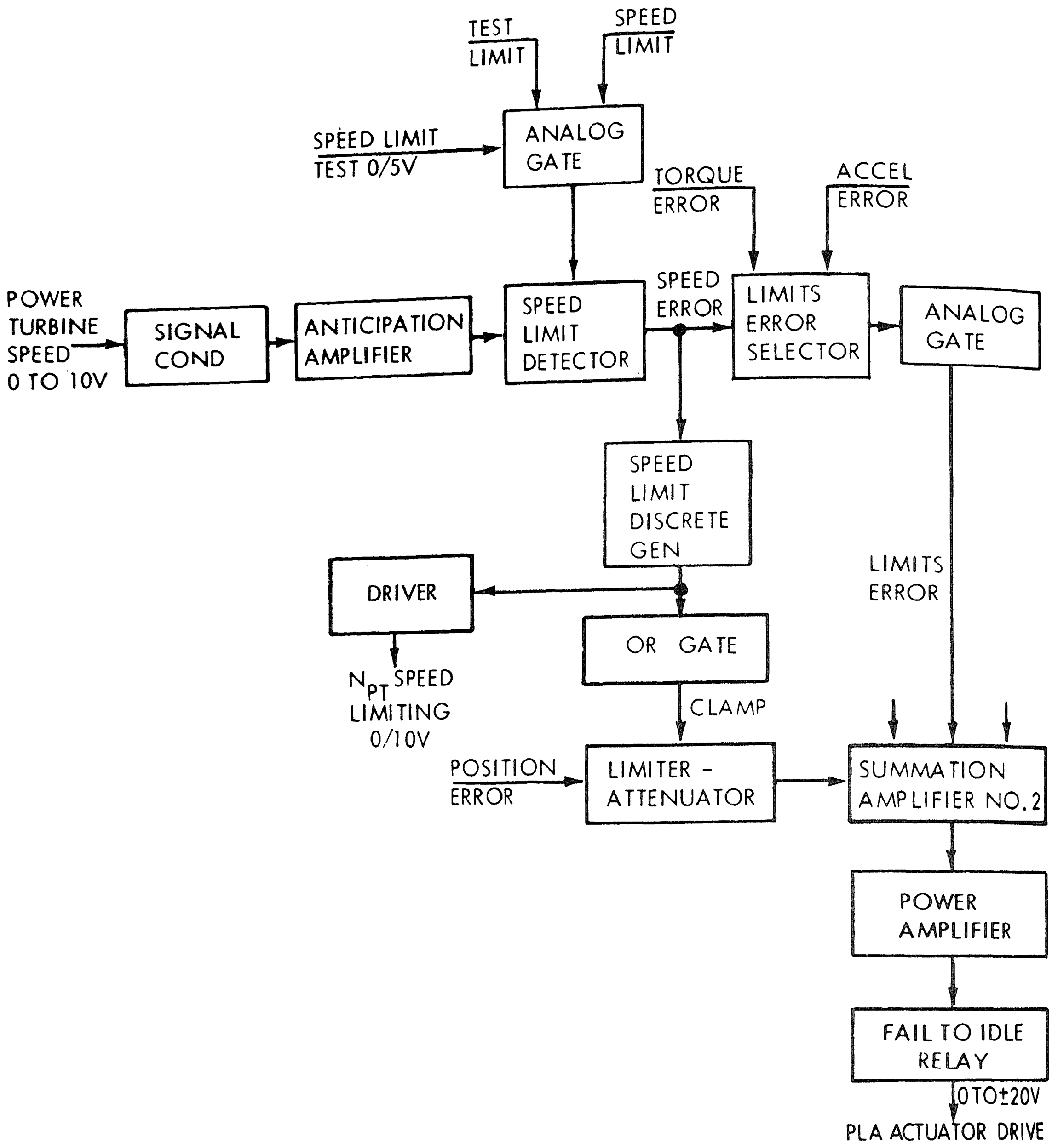
The speed error signal is also applied to the limits error selector (25) with the torque error and acceleration error signals. Again the output of the selector is the strongest of the three signals. This error output is sent through the analog gate (26) to summation amplifier No. 2 (11). When in speed limiting (as it was in torque limiting), the amplitude and polarity of the speed error signal will overcome the limited-attenuated position error signal. This then provides the output signal needed to drive the PLA actuator to the position where PT speed is limited to the preset limit. When PT speed is below the limit, the output of the speed limit detector is zero. In this case, no speed error is generated. This then allows the limiter-attenuator to pass the position error signal unchanged.

PT SPEED LIMITING DISCRETE SIGNAL.—The output of the speed limit discrete generator (39) is also sent uplink to the propulsion consoles. In this case, the signal output is a 10-volt d.c. signal produced by the driver (40). When this signal is produced, it indicates speed limiting is in effect.

SPEED LIMIT TEST.—The speed limiting circuitry has a test feature that allows testing of the speed limiting circuitry. When placed in test, a discrete 5-volt signal (41) is sent to an analog gate (42). This gate selects the test limit. This test limit is 75 percent of the normal speed limit. This allows checking of the PT speed limiting control at reduced PT speeds.

Acceleration Limiting

The acceleration limiting circuits are used only in the FSEEs installed on DD-963, DDG-993, and CG-47 class ships. The circuits are found on all the FSEE B cards, but they are not used on FFG-7 class ships. This is accomplished by adjusting the circuit out of the system.



293.52.9

Figure 7-13.—Speed control.

The acceleration control circuit (figure 7-14) provides limiting if the PT acceleration attempts to exceed a preset limit. The same PT speed signal used in speed control (35) is used in acceleration control. After being conditioned in the signal conditioner (36), the signal is sent to a differentiator (43). This responds only to changes in speed. The derivative of speed is acceleration. The differentiator calculates this derivative. It outputs a signal proportional to the rate of speed change and the time constant of the differentiator. This acceleration signal is compared in the acceleration limit

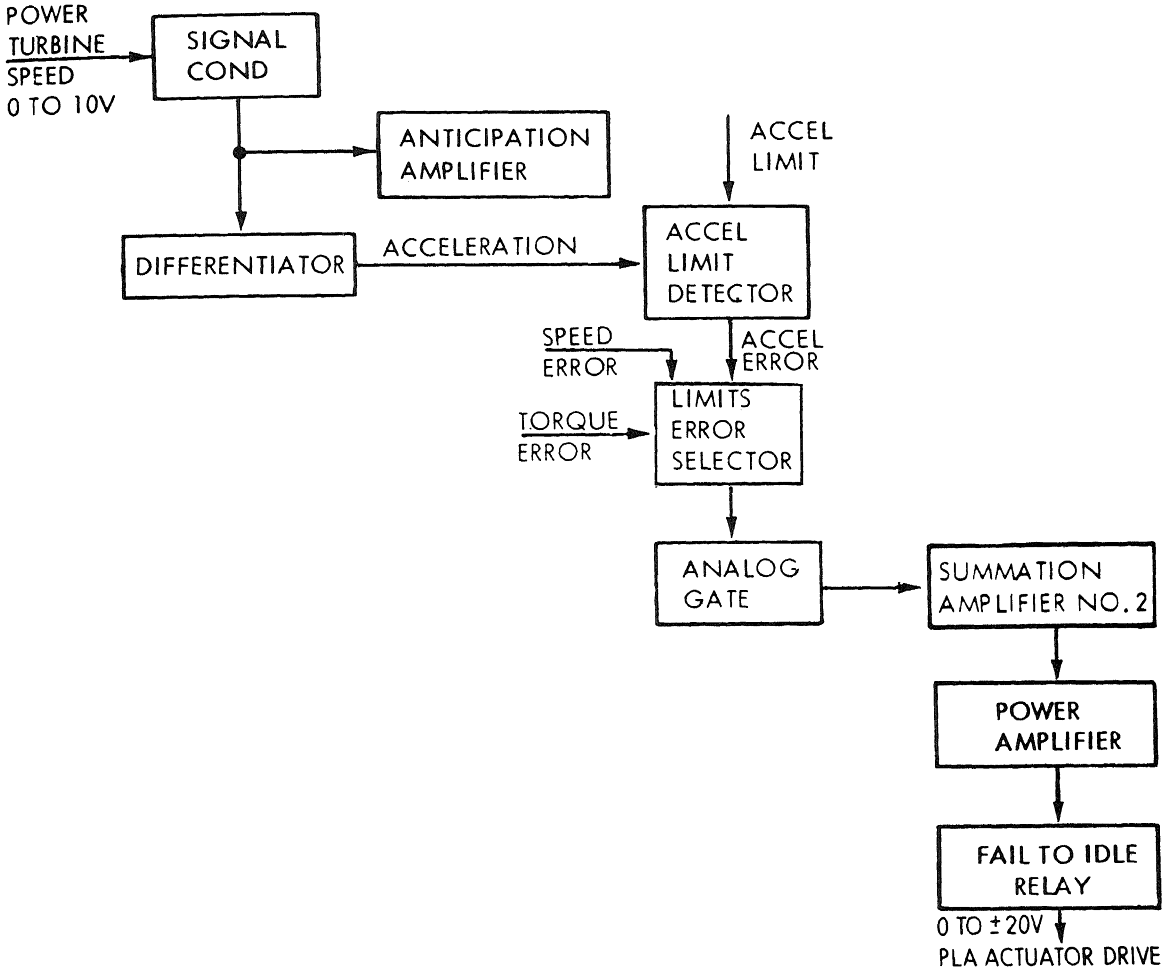


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Figure 7-14.—Acceleration control.

detector (44) against a preset limit. If the signal exceeds this limit, the detector will output a signal proportional to the amount the limit is exceeded. This output signal is called the acceleration error. This error signal is sent to the limits error selector. The selector then picks the strongest of the three error signals (speed, acceleration, and torque) and sends it to the analog gate. From the gate, the signal is sent to the summation amplifier No. 2. At an amplitude determined by the PT acceleration and the time constant of the differentiator, the amplifier provides an output to drive the MFC lever to a reduced power setting. This is because of the polarity of the signal. The error signal controls the rate of change of the MFC lever. It adjusts fuel flow to the engine to reduce PT acceleration.

Command Loss

If the PLA command signal exceeds the maximum limit, or if it falls below the minimum limit, the command loss circuitry will drive the PLA to the idle stops. This is done by closing the fail to idle relay. The command loss signal also sends an uplink signal to the propulsion consoles. The signal shows the command loss condition.

The command loss circuit (figure 7-15) receives its signal from the output of the command unity gain isolation amplifier (8). It is sent through the low pass filter (45) which provides a short (185 millisecond) time delay. This allows short term command losses to be ignored. This signal then goes to two command loss detectors (46 and 47). One detector monitors the minimum limit; the other checks the maximum limit. These limits are set by the V_{ref}. If the command signal is in limits, then the output of both of the detectors is zero. If the command signal falls out of limit (either high or low), one of the detectors will output a discrete signal. This signal is then sent to an OR gate (48). The output of the OR gate goes through a gate (17) and driver (18) to the fail to idle relay (13). This relay applies a signal to the PLA actuator to drive the engine to idle.

The output of the OR gate is also applied to another OR gate (49) through a driver (50) to output the system fail uplink signal (51).

Fail Detection

A system malfunction is when the error signal to the PLA actuator exceeds a predetermined level for a predetermined time. When this malfunction occurs, a fail to idle signal is generated to send the MFC lever to the idle stop position.

In figure 7-16, the fail detection circuit is shown. The output of the summation amplifier No. 2 (11) (error signal) is sent to two failure detectors (53 and 54) via the low pass filter (52). This filter is used as a time delay. One failure detector is used to monitor positive signal error; the other monitors negative signal error. If this time delayed error signal exceeds the V_{ref}, one of the two detectors will send out a discrete signal. This signal is sent to an OR gate (48). The output of this gate (the same one used by the command loss circuit) is sent through a gate (17) and

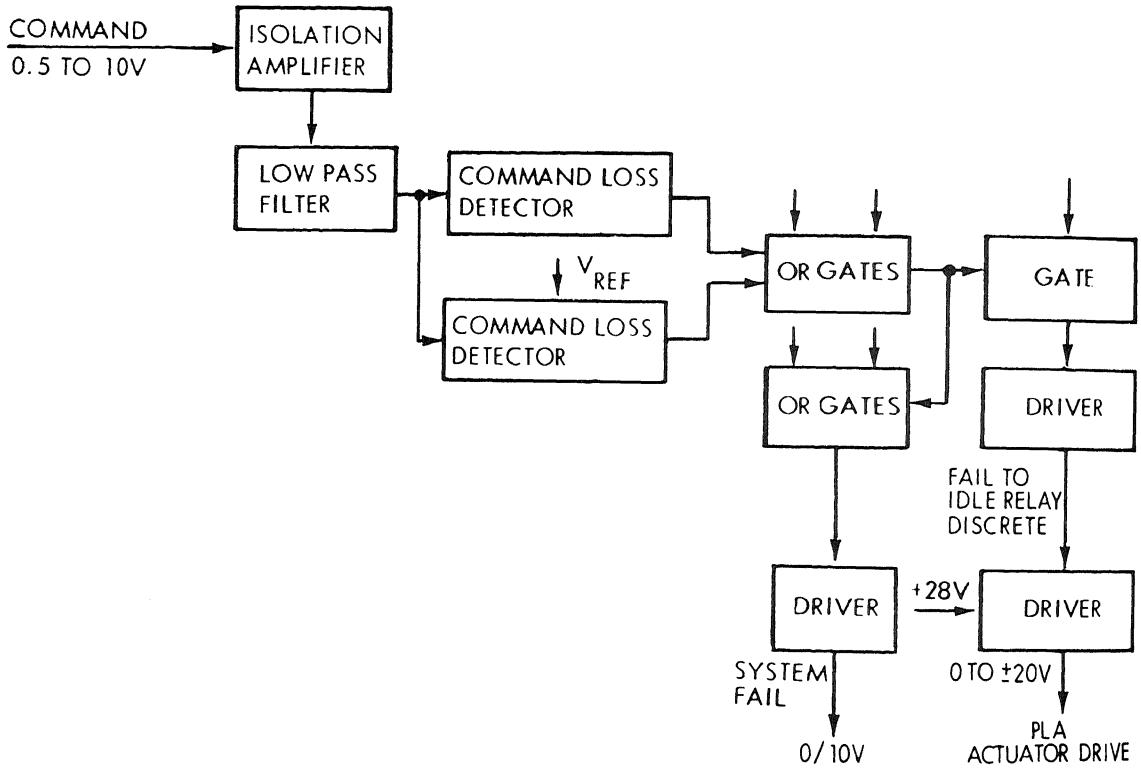

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Figure 7-15.—Command loss protection.

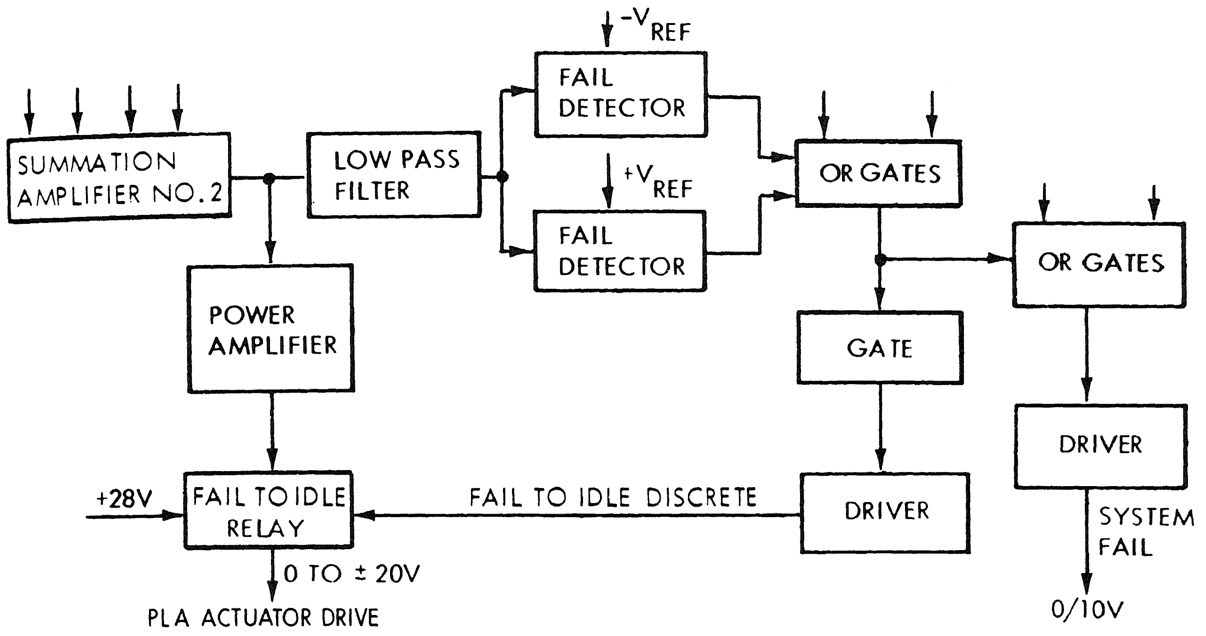

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Figure 7-16.—Fail detection.

driver (18). This causes the fail to idle relay to position the MFC lever to the idle stop. If the error signal drops below the level of both detectors, the circuit assumes the malfunction is corrected. It reconnects the PLA actuator back to the output of the power amplifier (12).

The output of the OR gate (48) is also applied to another OR gate (49) and driver (50). This then outputs the system fail uplink signal (51).

System Fail Monitor

Three conditions will cause the system fail discrete signal to be sent uplink. First, the signal may be generated when the fail to idle relay is driving the PLA actuator to idle. This is because of the command loss or fail detection circuits mentioned before. Second, the signal may be generated when the MFC lever is at the mechanical stop. Thirdly, the signal may be generated when the MFC lever is in the idle position and an overtorque discrete signal exists.

The system fail monitor circuit is shown in figure 7-17. Three inputs are sent to the system fail OR gate to generate the uplink signal. Any one of the three inputs will trigger an output. The first input comes from the OR gate (48) that receives signals from the fail detectors and command loss detectors. The second input comes from the idle stop detector (55). The idle stop detector will output a discrete signal when the PLA actuator position (from the potentiometer slider in the actuator) is below the idle set point. This set point is the V_{ref} applied to the idle stop detector. The third input comes from the three-input AND gate (56). These AND gate inputs come from the idle position detector (5), the overtorque discrete generator (23), and the torque test signal (31) from the receiver (32). This AND gate outputs a signal only when the PLA is at idle, an overtorque condition exists, and the torque computer is not in the test mode. The AND gate signal will then trigger the OR gate (49) to output a system fail from the driver (50).

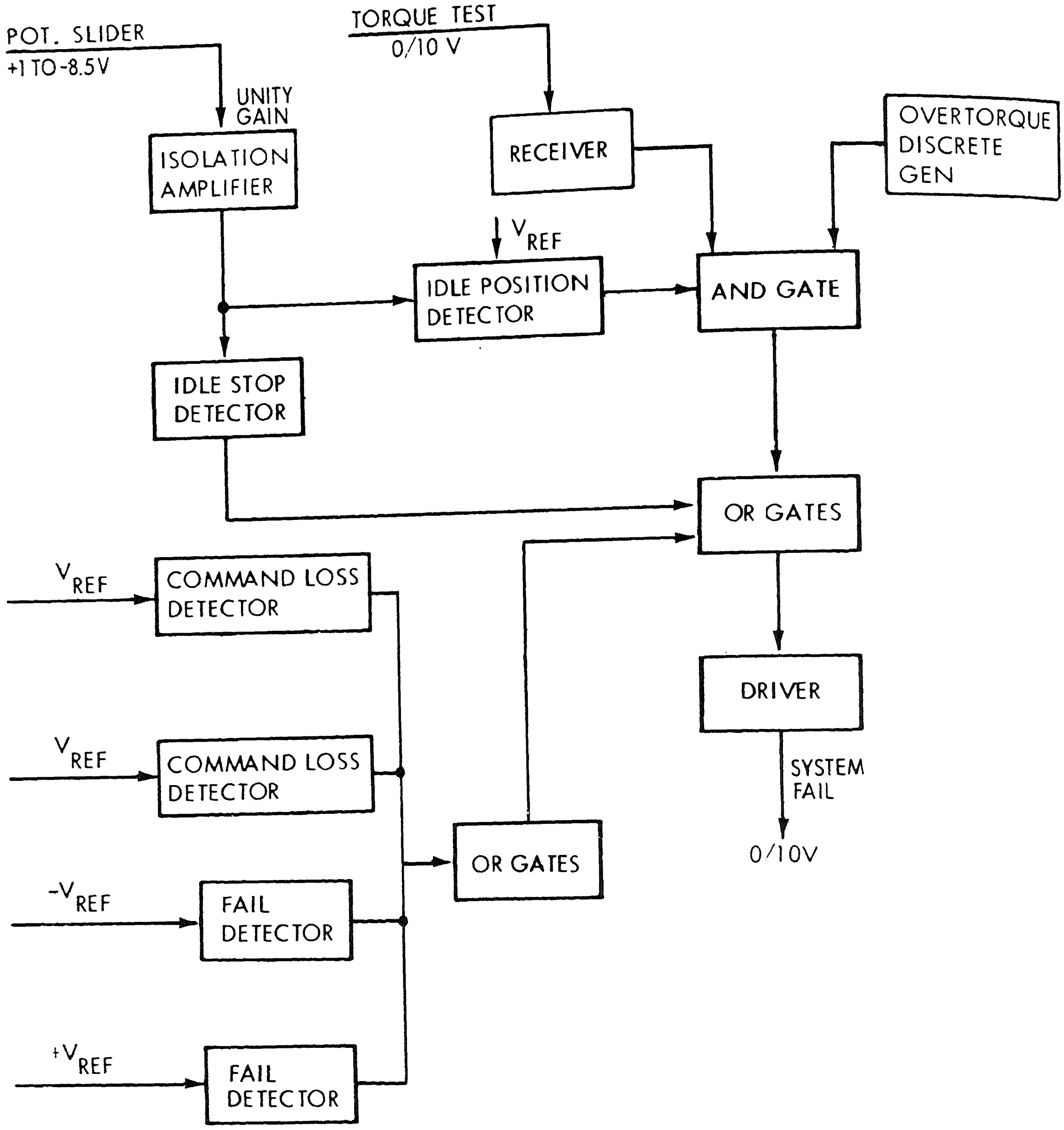

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Figure 7-17.—System fail monitor.

Battle Override/Reset Control

Battle override (figure 7-18) inhibits all torque, speed and acceleration limiting, and the fail to idle protection.

The battle override signal (57) is sent to the FSEE from the propulsion console. This signal is converted to a logic level by a receiver (58). The output of the receiver is sent to two gates to perform the battle override functions. The first gate (34) outputs a signal to open the normally closed analog gate (26). This prevents the torque, speed, or acceleration error from being sent to summation amplifier No. 2 (11). The other gate (17)

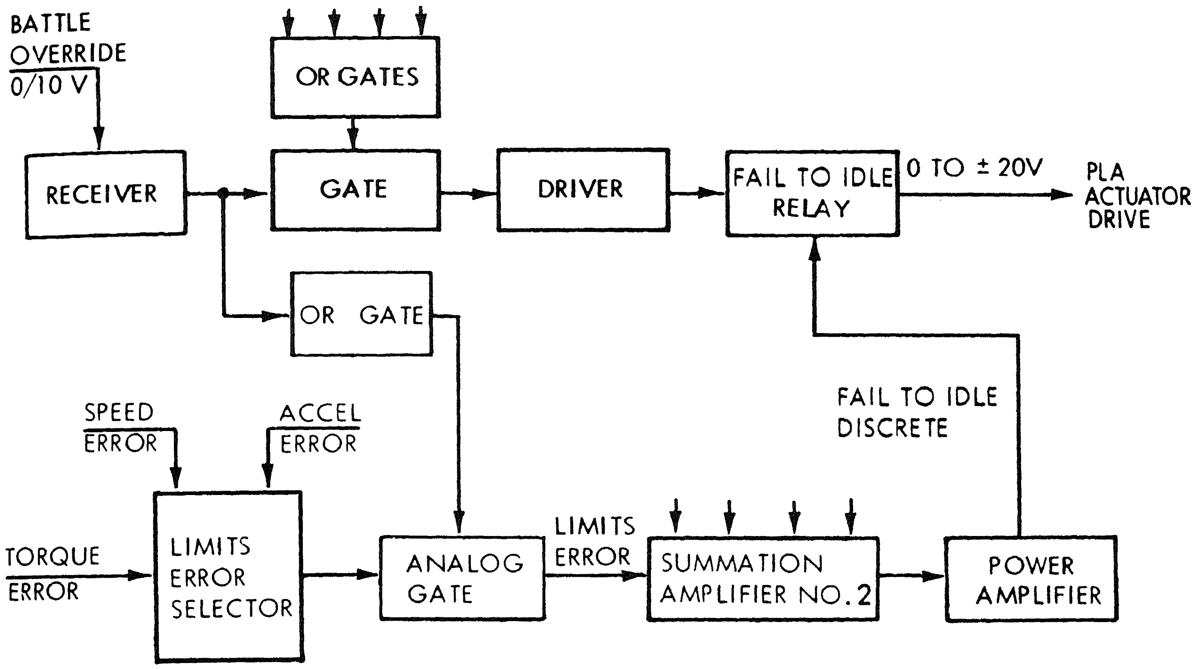

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Figure 7-18.—Battle override.

affected by battle override controls the fail to idle relay. When the battle override signal is applied, this normally closed gate is opened. This prevents the output of the OR gate (48) from triggering the fail to idle relay and sending a signal to position the MFC lever to idle.

Because battle override disables many control features of the FSEE, its use is carefully controlled. Normally, only the commanding officer may give permission to use the battle override feature.

PT OVERSPEED ELECTRONICS

The FSEE contains two identical circuit boards per engine used for overspeed protection. These are the D cards. Each card receives its signal from its own speed pickup and controls both fuel valves. (Recall, there are two fuel solenoid valves piped in series, but wired in parallel.) This allows for two independent speed channels and two independent overspeed trips.

The overspeed control circuits function to shut down the engine if a PT overspeed, PT underspeed, or a loss of control power to the control circuit occurs. When any of these conditions exist, the circuit will de-energize the engine fuel valves. This will shut off the engine fuel supply. The circuit is a latching type. This prevents the fuel valves from opening when the condition clears. You must use an external reset to reset this circuit.

Figure 7-19 is a block diagram of the PT overspeed switch. It shows the circuits of two D cards. The speed pickups of the PT (covered in chapter 3) send a frequency signal to the D card proportional to the PT speed. This signal (one from each pickup) enters the card and goes to a signal conditioner (1). The signal conditioner and frequency to voltage converter (2) changes the frequency level to a voltage level that corresponds to it. This voltage is then compared to two preset limits in the limit 1 (3) and limit 2 (4) comparators. The limit 1 comparator is used to detect loss of speed signals. This limit is adjustable over a range

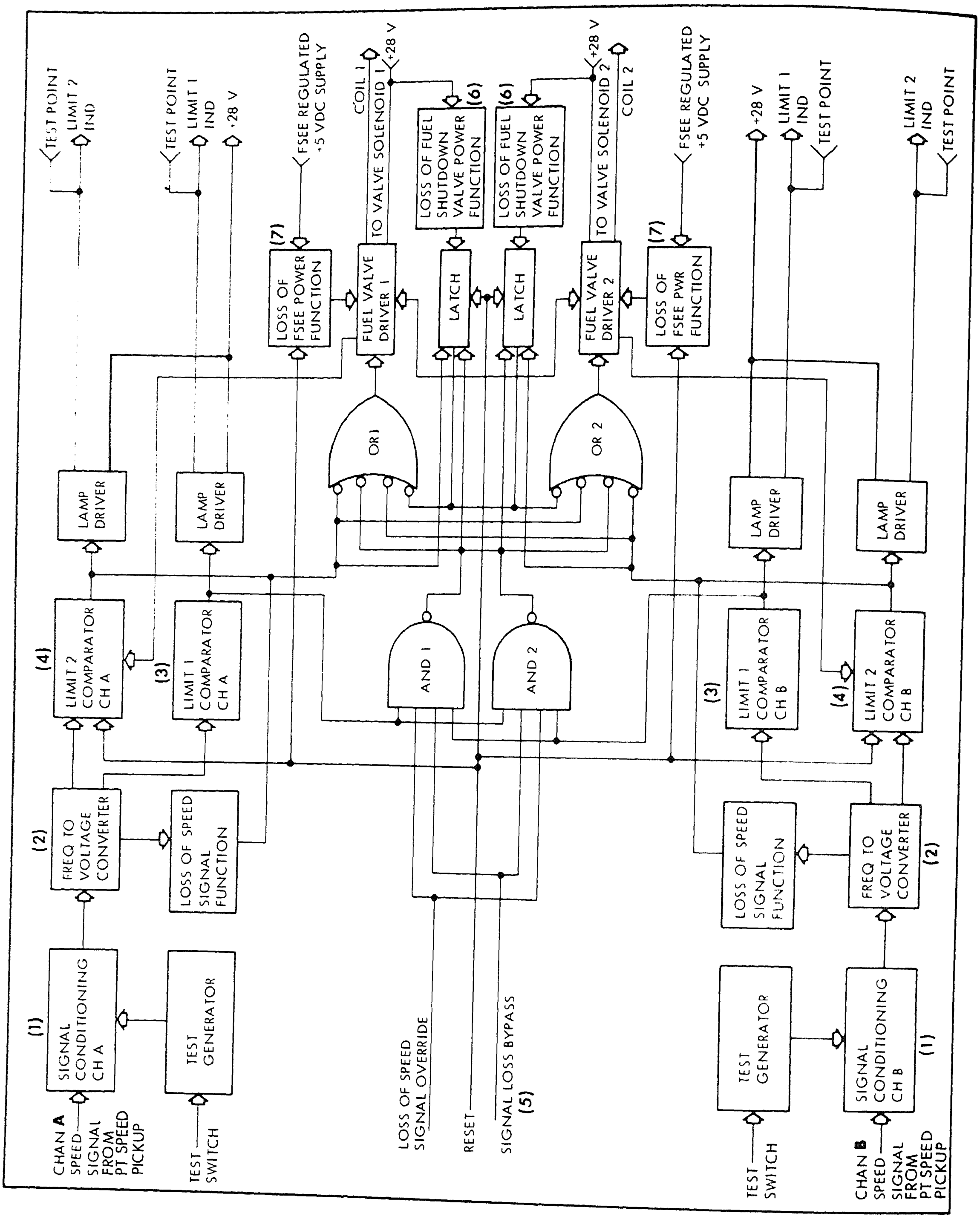

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Figure 7-19.—Power turbine overspeed switch block diagram showing the circuits of two D cards.

of 100 to 725 rpm. To generate the signal needed to close the fuel valves, both channels A and B must detect a speed lower than the preset limit. This set point is normally near 100 rpm PT speed. The limit 2 detector is used to detect PT overspeeds. This limit is adjustable over a range of 3000 to 4000 rpm. It is normally set at 3960 ± 40 rpm. If either channel detects an overspeed condition, a signal will be generated to shut the fuel valves.

Because during start-up the PT speed is below the limit of the No. 1 comparator, some method must be used to allow the fuel valves to remain open. This is done by an input from the PLA electronics known as signal loss bypass (5). This signal is present when the PLA actuator is between idle and a nominal 30 degrees. When the PLA is advanced above this limit, the PT speed must be above 100 rpm. If the engine is not above 100 rpm, it will shut down.

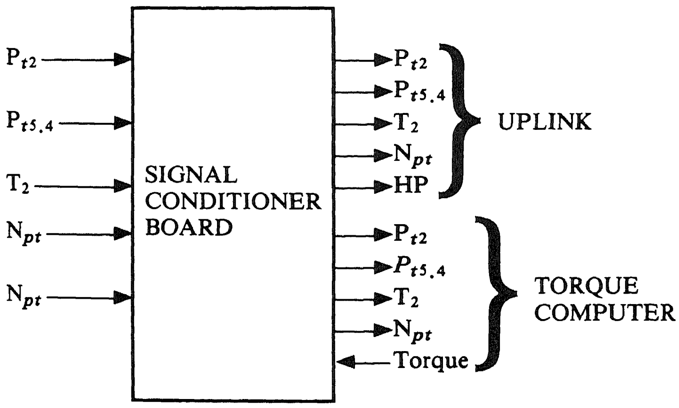
Each channel has a test generator used to apply a test signal to the channel. The FSEE has pushbuttons used to test the overspeed trips. When depressed, these pushbuttons activate the test generator which simulates an overspeed condition. This will activate the overspeed trip alarm and shut the fuel valves. You should only perform this test on nonrunning engines.

The D cards also have voltage detectors (6) and (7). The first detectors (6) monitor the voltage going to the fuel valves. If this voltage drops below 20 volts d.c. for 10 milliseconds (msec), the fuel valves close and are latched off. Also, loss of FSEE 5-volt d.c. power will signal the fuel valves to close and latch them until reset. CAUTION: Never depress the PT overspeed reset pushbutton on the propulsion consoles after an underspeed, overspeed, or loss of voltage until the engine comes to a complete stop. Doing so could cause the fuel valves to reopen and enable a restart of the engine. This restart may cause severe damage to the GT.

SIGNAL CONDITIONER

Each engine has a signal conditioner card (E card) used to condition speed, pressure, and temperature sensor signals. (Each FSEE, therefore, has two E cards.)

Five analog signals are sent to the signal conditioner (figure 7-20). These are P_{t2}, $P_{t5.4}$, T_2, and two N_{pt} speed signals (one from each pickup). The conditioner also processes one internal signal. Four of the signals are sent to the torque computer. Five signals are buffered and sent uplink to the propulsion console. The two pressure signals, P_{t2} and $P_{t5.4}$, are received from



ABBREVIATIONS

HP	HORSEPOWER
N_{pt}	POWER TURBINE SPEED
P_{t2}	COMPRESSOR INLET PRESSURE
$P_{t5.4}$	POWER TURBINE INLET PRESSURE
T_2	COMPRESSOR INLET TEMPERATURE

Figure 7-20.—Signal conditioner inputs and outputs.

transducers as a 4- to 20-mA signal. These are converted to 0 to + 5 volts d.c. for use in the torque computer. They are also sent to a buffer amplifier with a two-to-one gain to output a 0- to 10-volt d.c. uplink. The one temperature signal, T_2, is inputted to the signal conditioner as a resistance change from an RTD. This signal is also converted to 0 to 5 volts d.c. for the torque computer. It is converted to 0 to 10 volts d.c. for uplink. A voltage regulator is used to convert a − 15 volt d.c. bus supply to a precision − 12 volt d.c. for use in the temperature bridge and speed signal conditioner circuits. The speed inputs from both PT speed pickups are sent to the conditioner as frequency signals proportional to the PT speed. Switching is provided to switch from the primary input to the alternate input in case of primary failure. Two multiplying tachometers are used to multiply this frequency by a voltage level. In the first tachometer, the reference voltage is fixed. The output is directly proportional to the PT speed. This output is sent to the torque computer and also uplink. The second tachometer uses a torque proportional voltage for comparison. This voltage, when multiplied by PT speed, produces a voltage proportional to the horsepower developed by the engine. This voltage is then sent uplink for use in the propulsion consoles.

TORQUE COMPUTER

Seven of the circuit cards per engine make up the torque computer. These are:

Card Designation	Name
F	Input/Output No. 1
H	Control
J	Arithmetic
K	Address Control
L	Memory
N	Input/Output No. 2
P	Sub Command

The torque computer is a special purpose computer used to calculate engine torque. A block diagram of the torque computer is shown in figure 7-21. Four analog inputs are used by the computer for its calculation. These are T_2, P_{t2}, $P_{t5.4}$, and N_{pt}. They are supplied to the computer from the signal conditioner and inputted on the F card (input/output No. 1). These four inputs are filtered and sent to the analog multiplexer (2). The output of this multiplexer is sent to the N card (input/output No. 2) to an analog to digital (A/D) converter (3). There the signals are converted from analog to digital. The four digitized signals are sent (along with two other digital signals, bleed air, and test) to a digital multiplexer section (5). They are forwarded to the main data bus (6). The output of the multiplexer section is then sent to the memory (7) for storage. The memory has both Read Only Memory (ROM) and Random Access Memory (RAM). ROMs are used to store two program sections and a data table. Two ROMs are used to store the sequence of instruction needed to solve the torque computations. The third ROM, storing the data table, supplies information to another part of the computer. That part of the computer calculates torque as a function of temperature.

The RAM is used to temporarily store data used in the torque calculations. The input data, after being digitized, is stored in the RAM before making the torque calculations.

The sub command board (P card) receives the program instructions from the memory (the ROMs). This section then decodes these instructions and provides the output control lines to control the system. The control lines are used to output 35 exclusive lines of control. These control lines execute control of the arithmetic functions as well as the inputs and outputs of the computer.

The arithmetic section (J board) has three registers—the A, B, and C (8, 9, and 10). The A register is also known as the accumulator register. It is used to store the results of the arithmetic functions. The B and C registers are used to store the numbers being used in the operation. The

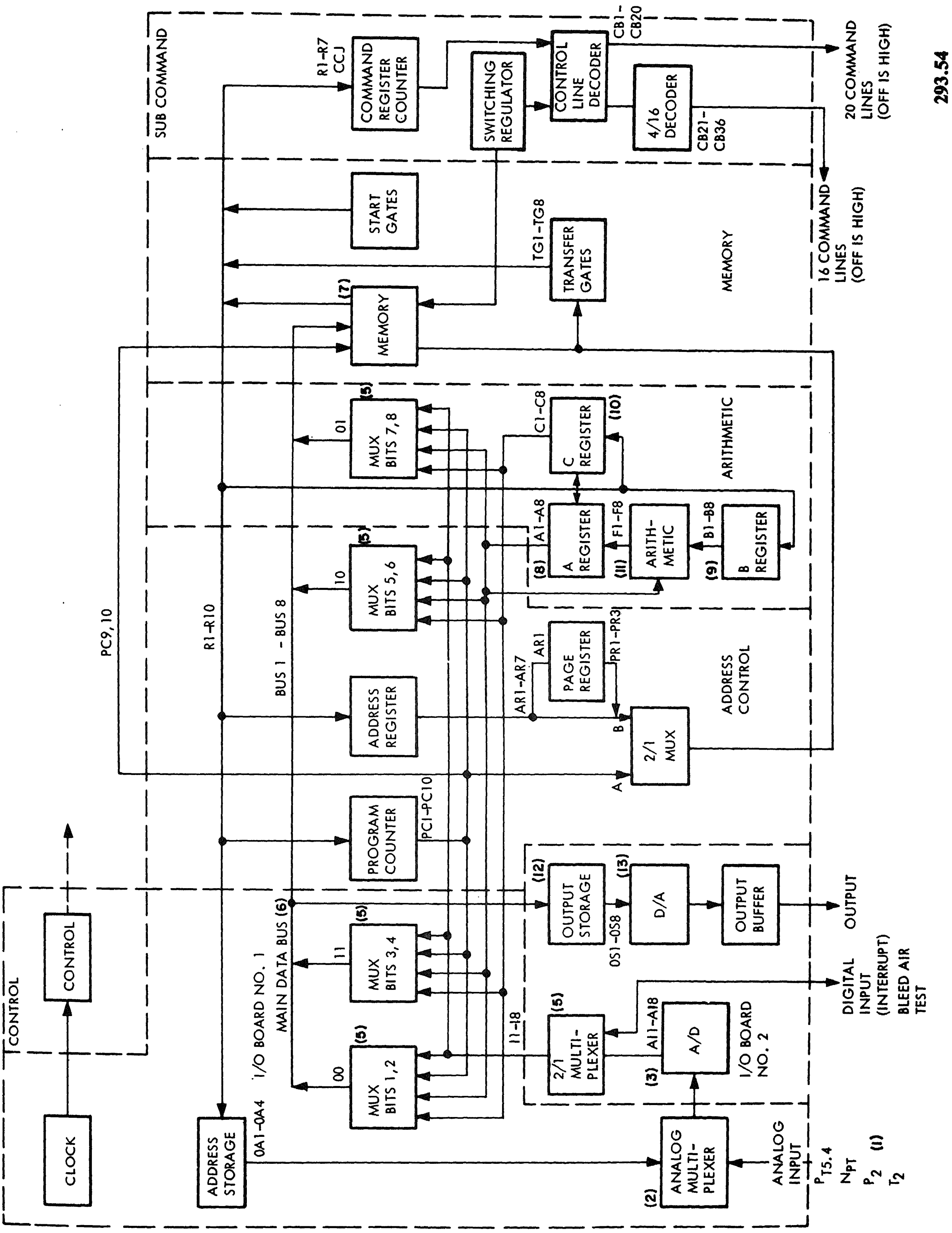


Figure 7-21.—Torque computer block diagram.

arithmetic board receives the control signals from the sub command. It uses these signals to execute, in the proper sequence, the arithmetic calculations used to compute torque. The arithmetic logic unit (11) performs the actual operations such as adding, subtracting, and comparing. The result of these computations, when properly scaled, becomes the output torque value. The digital output of the A register is then sent back to the multiplexer section (5) to the main data bus (6). Then the signal is sent to the output storage register (12). There it is converted to an analog signal in the D/A converter (13). The analog output is then buffered and sent out of the computer to the components that use this torque signal.

The torque computer is constantly resetting and recalculating torque. It operates at a much faster rate than the propulsion system can react. For a more detailed explanation of the torque computer, refer to the reference at the end of this chapter, *Propulsion Gas Turbine Module*, LM2500, Volume 1, Part 1.

−12 VOLT D.C. AND −15 VOLT D.C. POWER CONVERTER

One circuit card found only in FFG-7 FSEEs but not in DD, DDG, or CG FSEEs is the T card. This card is used as an independent power supply for the B channel of the PT overspeed card (D card).

It provides uninterrupted overspeed protection if a failure of the −12 volt d.c. regulated voltage from the signal conditioner card occurs.

OVERSPEED INDICATOR PULL-UP RESISTOR

The overspeed pull-up resistor card (M card) is used only on the DD-963, DDG-993, and CG-47 class ships. Only one M card is used in these FSEEs and serves both GTs. This card has eight 2000-ohm, 1-watt resistors, divided into four groups of two each. These resistors are used as pull-ups for the PT overspeed switch indicator circuits.

FFG-7 START/STOP SEQUENCER

The start/stop sequencer is installed in the FSEE on FFG-7 class ships. It provides signal conditioning, monitoring, and logic circuits required for safe GT starting and stopping. Nine circuit cards are used for this feature. Three cards (the X, Y, and Z cards) are signal conditioners. Four of the cards are logic cards (the AB, AD, AE, and AC cards). The other two cards are a transmitter card (AA) and a thermocouple amplifier card (V).

The start/stop sequencer provides the following functions.

- Signal conditioning of gas turbine parameters
- Monitoring of vital parameters
- Sensing out-of-limits instrumentation signals
- Signal conditioning output status signals
- Initiating automatic control signals
- Receiving and processing operator commands

SEQUENCE MODES

The start sequencer has three sequence modes available. These modes are auto, manual, and auxiliary (or test) mode.

In the auto mode, when commanded by a signal from the propulsion control console (PCC), an automatic start-up of the GT can be performed. This auto start sequence using a programmed time sequence monitors and controls the engine starting. Parameters monitored include N_{GG}, $T_{5.4}$, fuel manifold pressure, and lube oil supply pressure. If these parameters are not within limit during start-up, the sequencer will initiate an immediate automatic shutdown.

In the manual mode, an operator is required to initiate the starter on, fuel on, and ignition on

commands. When the sequencer receives a manual start command, it provides the time sequence and engine parameters for the operator's information. The conditions that would cause shutdowns in the automatic mode provide only an alarm in the manual mode.

The auxiliary mode (or test mode) is used to test the engine start components. When in this mode, the fuel and ignition cannot be activated at the same time.

In the auxiliary mode, the operator can check the fuel system without causing a start of the engine. This is done by manually motoring an engine, and at 1200 rpm, energizing the fuel valves. Then the operator checks the operation of the fuel system components. This is done by monitoring fuel supply temperature, pressure, fuel flow, and fuel manifold pressure. In this way, operation of the fuel pump, main fuel control, and fuel shutoff valves are checked. The shutdown valves normally are de-energized at the same time to shut down the engine. A fuel valve test mode allows you to test the valves alone to ensure proper operation of the valves. You can only do this test when PLA is at idle. (Also, you can perform a test of the ignition system independent of the fuel system tests.) The ignition test will cause the igniters to be on as long as the igniter pushbutton is depressed.

AUTO START SEQUENCE

Please follow figure 7-22 as we discuss the auto start sequence mode of the FSEE.

Several permissives are required for starting the GTM. These permissives require PLA to be at idle, GG speed to be below 3500 rpm, and various shipboard systems to be aligned. When the command to start is sent to the FSEE and the parameters are met, the sequencer will start the logic controlled start sequence.

The first command asks if the auto mode is selected. If not, no further action will occur. But if it has been selected, the command is sent to see if the auto start signal has been sent. If not, no further action will occur. But if the signal has been sent, the circuit will reset all alarms and the PT overspeed switch (reset to the D cards). After these alarms are reset, several commands are sent out. These commands open the starter air valve, energize three timers, and enable the ice detector circuit to function. The three timers are

- failure to start (achieves 1200 rpm in less than 20 seconds),
- failure to idle (achieves 4500 rpm in less than 90 seconds), and
- lube oil pressure delay (delays low lube oil pressure shutdown 45 seconds).

As the engine starts to rotate, the circuit will begin checking to see if it has reached 1200 rpm. If it has, the sequencer will energize the igniters. It will open the fuel valves and start a 40-second fail to lightoff timer. If 1200 rpm is not reached, it will (1) send out an alarm signal, (2) close the starter air valve, (3) de-energize the ice detector, and (4) wait for reset or restart.

After the engine's fuel system and igniters are enabled, the engine should start combustion. The circuit will start checking if the engine has reached above 400 °F $T_{5.4}$ within the 40-second fail to lightoff timer duration. (If it has, the circuit checks the fuel manifold pressure to see if it is above 50 psig.) If so, the engine timer and start counter are energized. Also, the sequencer begins checking rpm to see if it is above 4500 rpm. If 40 seconds elapse and $T_{5.4}$ is below 400 °F, (1) the fuel valves close, (2) the igniters are turned off, (3) a fail to lightoff alarm is generated, and (4) a 60-second monitoring delay is activated. This motoring delay allows the starter to continue rotating the engine. This is to purge out any fuel buildup for 60 seconds. After 60 seconds, the starter valve is shut, the ice detector de-energized, and the circuit waits to be reset or be restarted.

After combustion occurs, the circuit is waiting for 4500 rpm within 90 seconds. When 4500 rpm is reached (1) the igniters are turned off, (2) the

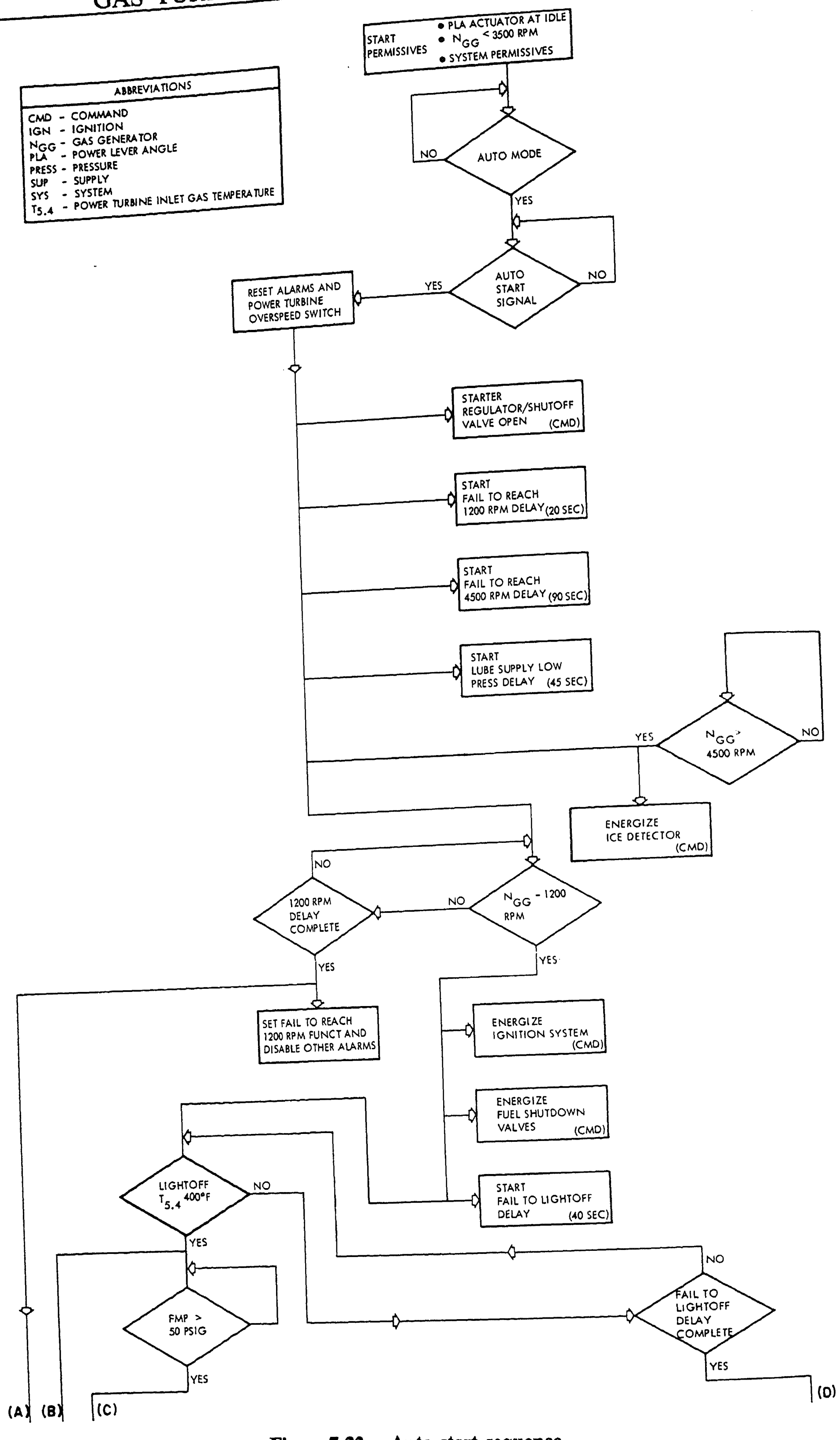


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Figure 7-22.—Auto start sequence.

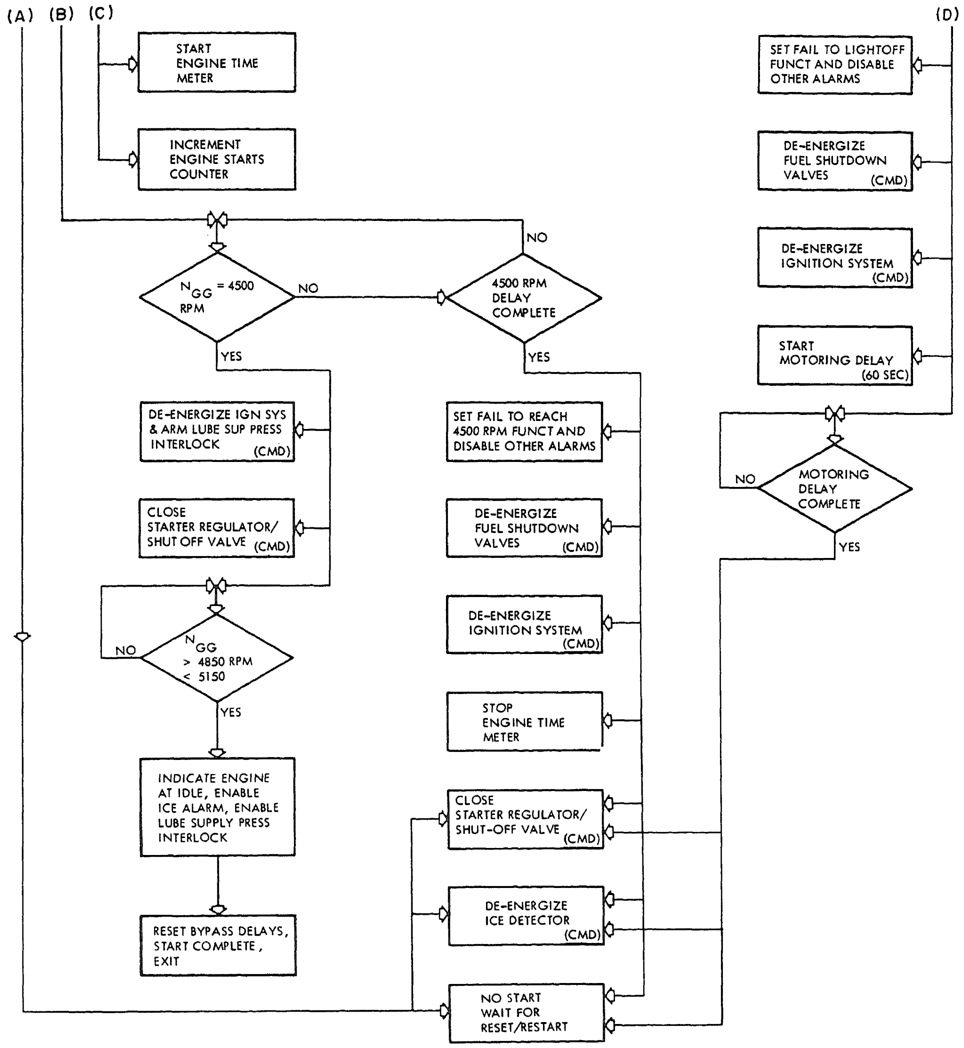

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Figure 7-22.—Auto start sequence—Continued.

low lube oil pressure circuit is armed, (3) the starter valve is closed, and (4) the circuit starts checking if engine speed is between 4850 to 5150 rpm. When this is achieved, the idle indication occurs. Then the ice alarm and the lube oil supply pressure interlock are enabled. The start is then complete. If the engine does not reach 4500 rpm in 90 seconds, the following occurs: (1) the fail to reach 4500 alarm sounds, (2) the fuel valves are shut, (3) the igniters are de-energized, (4) the engine time meter is stopped, (5) the start air valve is closed, (6) the ice detector is de-energized, and (7) the circuit waits to be reset and restarted.

MANUAL AND AUXILIARY SEQUENCES

Very little logic is involved in the manual or auxiliary sequence mode. In these modes, the protection of the engine is left more in the operator's

control. Figure 7-23 is a flow diagram of the manual and auxiliary control modes.

In the manual mode the operator depresses the starter air pushbutton, following the EOSS, to start the engine turning. If engine speed is above 4500 rpm, no command will be sent to the starter air valve. This is also used to turn off start air when the engine reaches this speed. After observing that the engine speed is above 1200 rpm, the operator can turn on the igniters and open the engine fuel valve. (NOTE: The starter air and igniter pushbuttons on the LOP are momentary-type pushbuttons. You must continue depressing them to keep the command active.) This action should cause combustion to occur. The operator, following the EOSS, has to release the igniter pushbutton to turn the igniters off. Even if the starter air pushbutton is still depressed, the starter will cut out at 4500 rpm.

The auxiliary mode logic is also very simple. It allows the operator to use starter air any time the engine is below 4500 rpm. This is regardless of fuel or igniter status. You may only open the fuel valves if the igniters are off. Likewise, you may only energize the igniters when the fuel valves are closed.

START/STOP CIRCUITRY

As we mentioned earlier, the start/stop sequencer uses nine circuit cards. We will discuss their functions in the following section.

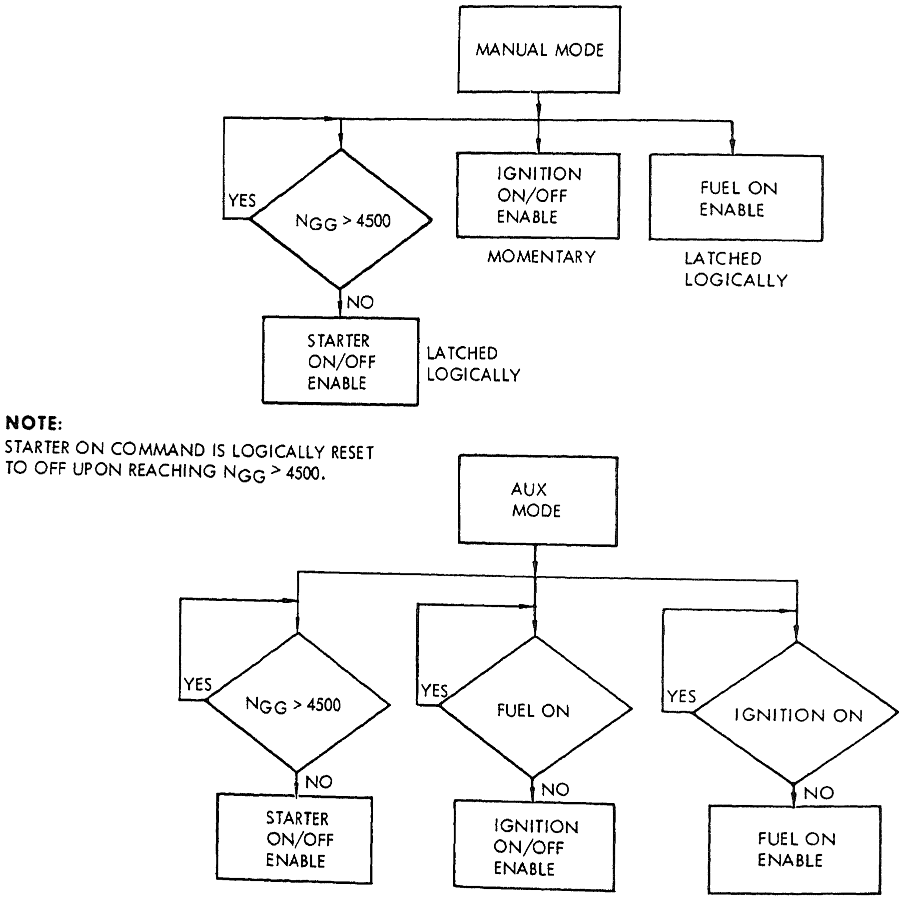

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Figure 7-23.—Manual and auxiliary start logic.

hermocouple Amplifier

The V card is the thermocouple amplifier. It erforms two functions. The first function is to onvert the $T_{5.4}$ signal into a 0- to 10-volt d.c. gnal proportional to 0 to 2000°F. The second inction is d.c. to d.c. conversion. This isolates e thermocouples and reference junction from round systems that may cause error inducing round loops.

ignal Conditioner No. 1

The No. 1 signal conditioner (the X card) is frequency sensing card. It senses N_{GG} from the agnetic pickup on the accessory drive. The put signal is conditioned to a voltage level pro- ortional to the speed frequency. The level is then ompared against adjustable limits to determine hen the speed is above 1200, 3500, 4500, 4900, 100, and 9700 rpm.

ignal Conditioner No. 2

The No. 2 signal conditioner (the Y card) pro- esses four signals. Two of these signals are ressure signals from two pressure transducers. hese are the fuel manifold pressure and the GT ibe oil supply pressure. The third signal comes om the thermocouple amplifier. The fourth gnal is an N_{GG} signal from signal conditioner o. 1. The two pressure signals are inputted as to 20 mA directly proportional to the pressure ensed by the transducer. These signals are con- erted to 0- to 10-volt d.c. voltage levels. The $_{5.4}$ and N_{GG} signals are inputted as 0- to 10-volt .c. voltages. These four 0- to 10-volt d.c. signals e sent to unity gain amplifiers and transmitted plink. The signals are also compared to detect e following levels.

- $T_{5.4}$—greater than 400°F
  greater than 1500°F
  greater than 1530°F

- Lube oil supply pressure—less than 6 psig
  less than 15 psig

- Fuel manifold pressure—greater than 50 psig

- N_{GG} signal loss

Signal Conditioner No. 3

The No. 3 signal conditioner (the Z card) is basically a relay driver. It activates the engine run time meter, the engine start counter, the ignition relay, the start air valve, and the ice detector relay. This board also gates the +28 volt d.c. to activate the No. 1 and No. 2 fuel valves.

Logic Card No. 1

The No. 1 logic card (the AB card) develops the control signals from operator commands or control logic. The signals are generated depending on the system status and the type of command to be generated. The first eleven signals generated depend on the reception of the signals received synchronized to the start/stop sequencer timing.

Logic Card No. 2

The No. 2 logic card (the AD card) has three timers used during engine start. These timers measure the following times for the listed functions.

Time	Function
20 seconds	Measured between starter on initiation and the time it takes to reach 1200 rpm. Generates fail to reach 1200 rpm signal.
45 seconds	Measured between starter on initiation and the time it takes to build up 15 psig lube oil pressure. Generates a lube oil supply pressure low after this period. If 6 psig is not attained, a lube oil supply pressure low shutdown command is generated.
90 seconds	Measured between starter on initiation and the time it takes to reach 4500 rpm. Generates a fail to reach 4500 rpm signal.

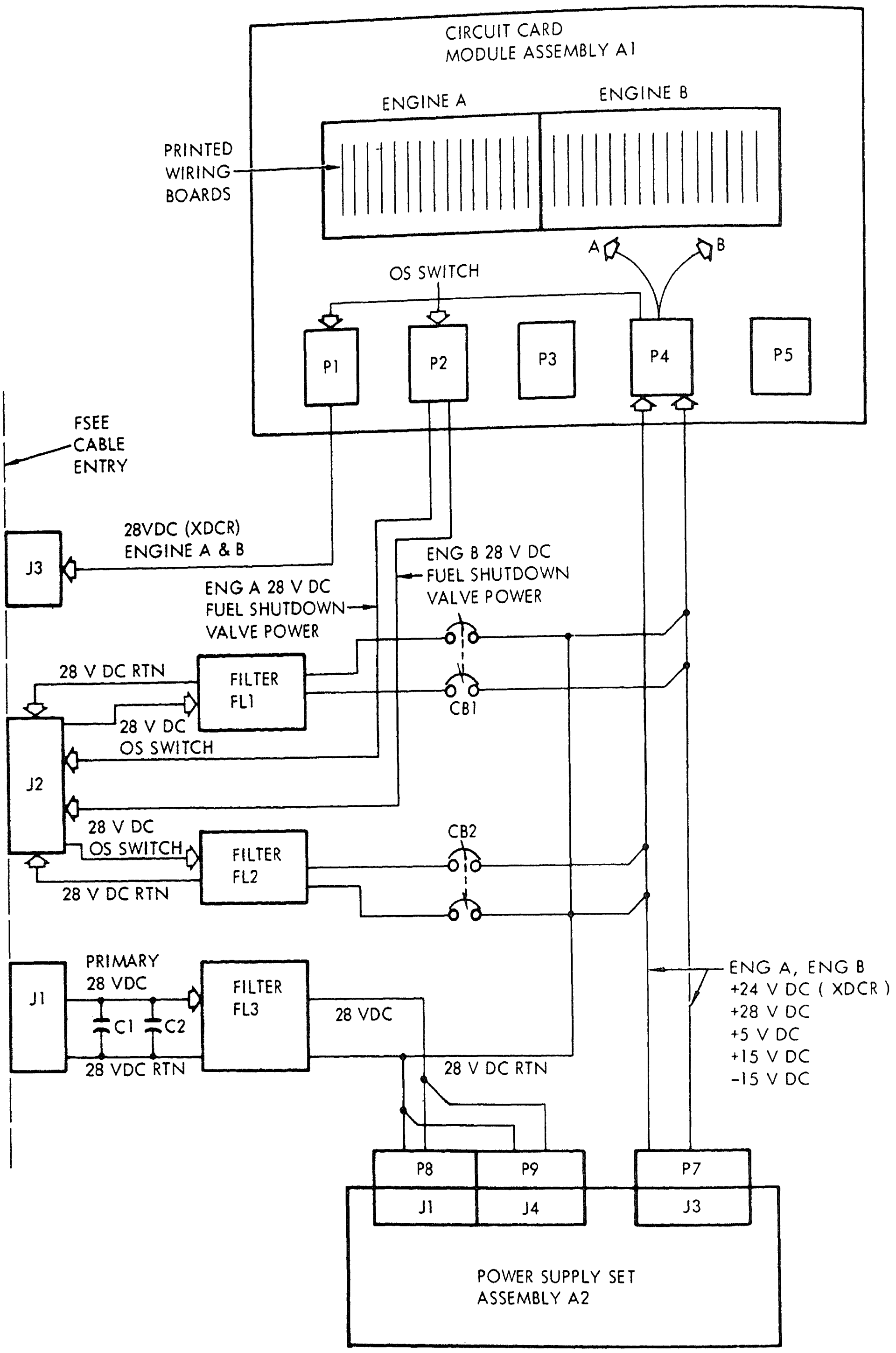

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Figure 7-24.—DD, DDG, CG, FSEE power supply.

Logic Card No. 3

The No. 3 logic card (the AE card) performs seven functions, two of which are timing functions. The first measures 40 seconds from the time the igniters are ordered on. In this time period, 400°F $T_{5.4}$ must be exceeded or a fail to lightoff signal is generated. The second timer measures 300 seconds (5 minutes) to allow cooldown between the time a normal stop is initiated and when the stop command is issued. Following is a description of the other five functions.

- Enables the run time meter and the start counter.
- Detects a flameout and generates a flameout alarm.
- Stores abnormal $T_{5.4}$ status.
- Stores normal ice detector enable and engine run start.
- Monitors status conditions and executes a stop when abnormal conditions exist.

Logic Card No. 4

The No. 4 logic card (AC card) provides many functions. These are timing, power-on reset, PT overspeed reset, alarm reset, status signal generation and processing, fuel valve testing logic, purge time stop delay counter, and normal stop fail counter.

POWER DISTRIBUTION

The two different models of the FSEE use two different power distribution sets. A major difference is that the FFG-7 class FSEE only distributes power whereas the other model FSEE generates all FSEE voltages from a 28-volt d.c. bus. Also, FFG-7 FSEEs use 115 volt a.c. whereas the other models use a lower voltage d.c.

DD-963, DDG-993, CG-47 FSEE POWER

This model receives 28 volt d.c. from the ship's power supplies to connector J1 (figure 7-24). The exception to this is power to the overspeed switch fuel shutdown valve solenoid. The shutdown valve solenoids are powered by 28 volt d.c. at connector J2. Three filters are used to eliminate high frequency line noise on the three power inputs. (FL1 and 2 are for fuel solenoids. FL3 is for primary power.)

The power supply set A2 has dual redundant power supplies. It distributes power to the circuit card assembly A1. Each pair of redundant supplies feed engines A and B. They are controlled by separate switches in the power supply set. The power supply converts and distributes the following voltages: +5 volt d.c., +15 volt d.c., −15 volt d.c., +28 volt d.c., and +24 volt d.c. for the P_{t2} and $P_{t5.4}$ transducers.

The power supply set has two run time meters to show how long the sets are powered up. They are powered by 24 volt d.c. The set also has the power amplifier for interface between the PLA circuit and the PLA actuator along with the fail to idle relay.

FFG-7 POWER DISTRIBUTION

The FFG-7 FSEE distributes both a.c. and d.c. power for use in the FSEE and in the module. All power is supplied by ship power supplies (figure 7-25). Input power to the FSEE is 115 volt a.c. and +5, +15, −15, +24, and +28 volts d.c.

The 115 volt a.c. is used for the flame detectors, ice detectors, and ignition exciters of both engines. The +24 volt d.c. is used as power for four transducers. These are the P_{t2}, $P_{t5.4}$, lube oil supply, and fuel manifold pressure. The +28 volt d.c. is used as power to the fuel solenoid valves. Each distribution assembly has a circuit breaker for this power. The other voltages are used in the circuit card racks for logic and control. The distribution assemblies also have the PLA power amplifier and the fail to idle relay.

SUMMARY

In this chapter we have discussed the operation and construction of the LM2500 FSEE. We have covered only how it works, not how to repair or adjust it. You must make repair or adjustment

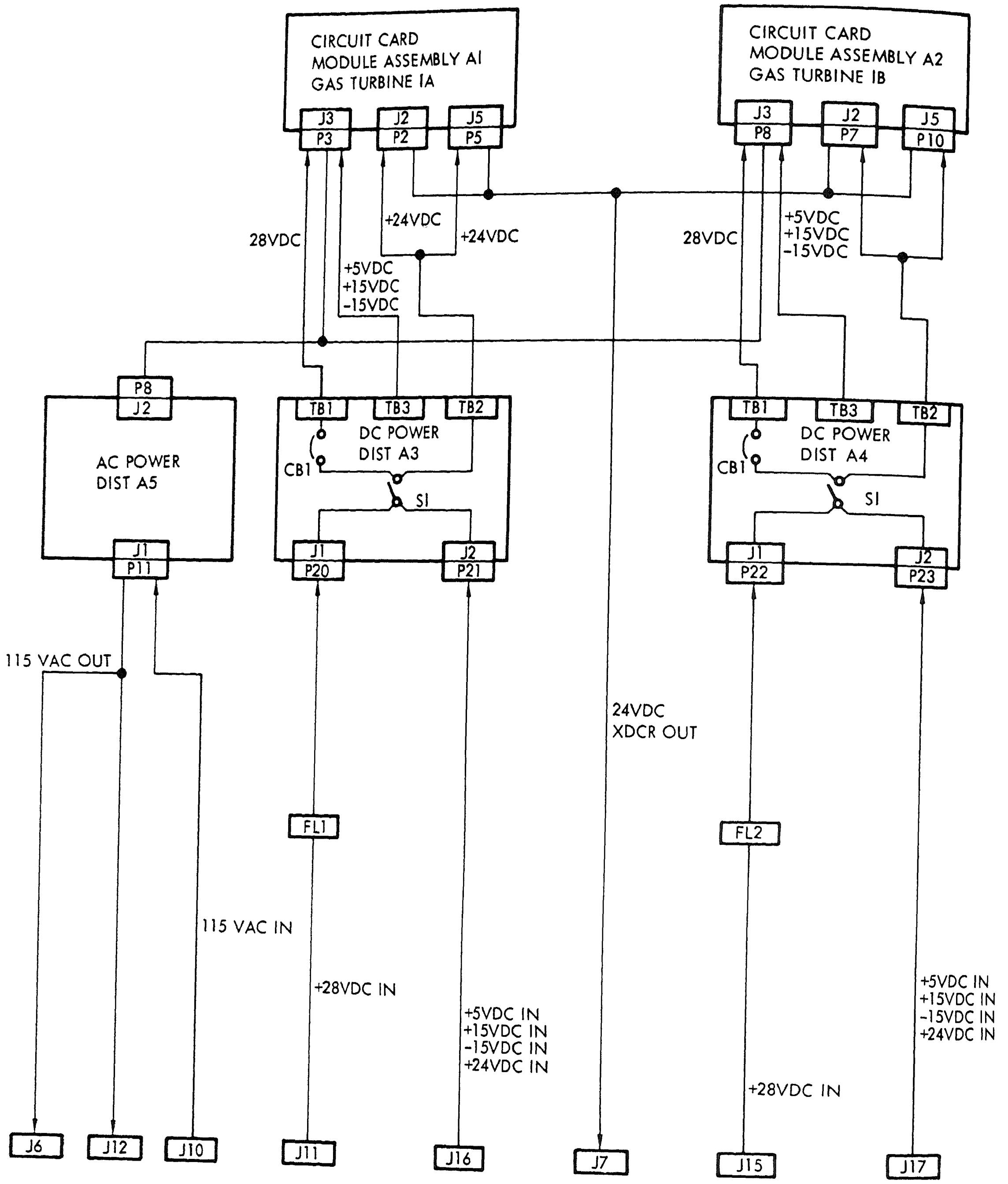

Figure 7-25.—FFG-7 FSEE power distribution.

operations strictly by following the manufacturer's technical manual. We have presented the information here to allow you to understand what functions are being performed when you make those adjustments. Knowing the information in this chapter should enable you to more quickly identify malfunctions. For more detailed and specialized information on each circuit, refer to the manufacturer's technical manual. Remember, only qualified technicians should make adjustments on the FSEE, and then only when the engine is shut down.

REFERENCE

Propulsion Gas Turbine Module LM2500, Description, Operation, and Installation, Vol. 1, Part 1, S9234-AD-MMO-010/LM2500. Naval Sea Systems Command, Washington D.C., 1 May 1982.

CHAPTER 8

ALLISON 501-K17 GAS TURBINE ENGINE

Until now our discussion has centered on the propulsion uses of GTs. This means we have covered only part of the job some GSEs are tasked with. On the larger gas turbine ships, such as the DD-963, DDG-993, and CG-47 classes, GSEs must maintain the ship's service gas turbine generator sets (SSGTGSs or GTGSs). These ships use two different GTGSs. They are the Model 104 on the DD and DDG classes, and the Model 139 found on the CG-47 class. Both types of GTGSs use the Allison 501-K17 engine as a prime mover. Although the engine is the same on both sets, many differences exist between the units. The Model 104 GTGS is a 2000-kW GTGS; the Model 139 is a 2500-kW unit. The 104 has a solid-state LOCOP that uses analog meters; the Model 139 incorporates a digital LOCOP with light emitting diodes (LEDs) used to display operating parameters. The Model 139 also uses a brushless exciter that replaces the brushes and slip rings found on the 104. Many other changes exist between these GTGSs. Most of these will be discussed in detail in this chapter.

Normally the GTGS is not attended while it is in operation. It is controlled either at the switchboard or the electric plant control console (EPCC). Neither of these control stations can monitor all the parameters of the operating GTGS. For this reason a monitor is usually required when making hourly rounds to log these parameters. Most often these monitors are GSs in the junior paygrades (E-5 and below). Therefore, you need to be able to quickly identify any impending casualty to the GTGS to prevent loss of the ship's electrical power. To do this, you must first be able to understand how the set is constructed, how its systems function, and how to operate it.

This chapter is written to give you, the junior GSE, enough information to begin qualification as an engine-room equipment monitor. It will also help you with your qualifications as an electric plant control console (EPCC) operator. EPCC operators are the watches that must monitor the electric plant. They are responsible for taking action to prevent loss of the electrical load during a generator casualty.

After reading this chapter and completing the associated NRCC, you should be ready to begin qualifications for the above-mentioned watches. You should also be able to identify and describe engine and generator components. The discussion of the engine systems will allow you to understand the operations of the various engine systems. We will discuss the generator control and monitoring equipment. This information will enable you to understand the procedures for starting, stopping, and motoring a GTG. Some switchboard operations will also be covered. Knowledge in these areas will allow you to understand frequency and voltage control functions.

As with the LM2500, the EOSS is provided to give you the correct procedures for operating this vital piece of machinery. This chapter serves only as a guideline for the operation of a GTG. Always use the EOSS when actually operating any engineering equipment. Using the EOSS will

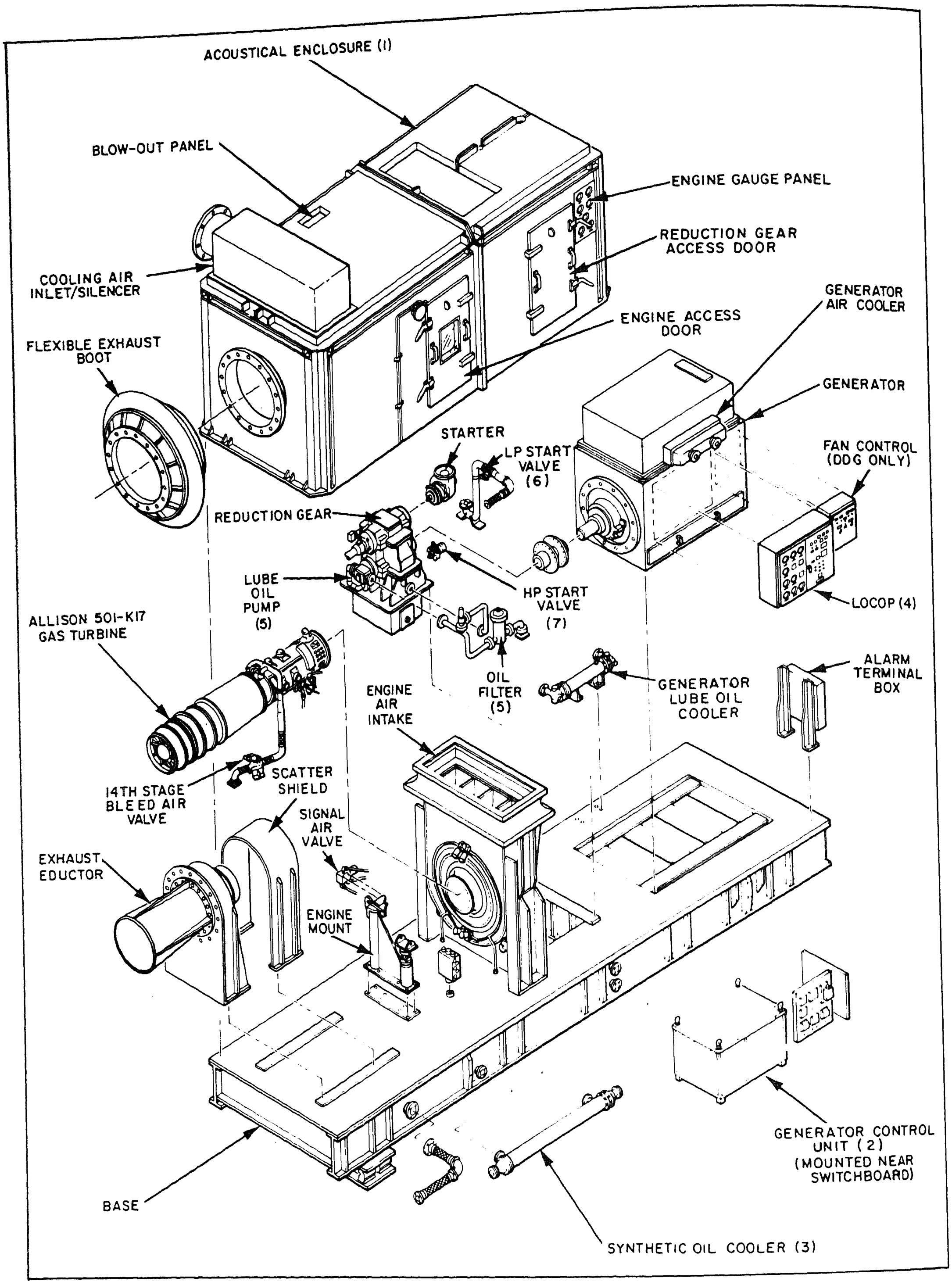

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Figure 8-1.—Model 104 gas turbine generator set.

prevent you from missing any steps that could damage a valuable piece of ship's equipment.

GENERAL DESCRIPTION OF THE GENERATOR SETS

Ship's service electric power is provided by three 2000-kW GTGSs on the DD and DDG classes. It is provided by three 2500-kW units on the CG-47 class. Under normal operating conditions, any two generators can supply the entire ship's demand. The third unit can be set up in auto-standby. It will then come on the line automatically in case either on-line unit fails. Each GTGS is a module consisting of a GT, a reduction gear assembly, and a generator. These are all mounted on a common base with associated engine controls and monitoring devices.

Figure 8-1 shows the equipment layout of a generator set. Refer to the numbers listed in parentheses after each description to locate the component in figure 8-1. Each module is about 25 feet long, 7 feet wide, and 9 feet high. The GT and reduction gear assembly are housed in an acoustical enclosure (1). Each generator has a remotely mounted generator control unit (2). The lube oil cooler (3) for each gas turbine/reduction gear system is mounted under the module base. GTGS No. 1 and GTGS No. 2 are located in engine rooms No. 1 and No. 2, respectively, on the second platform opposite the main engines. GTGS No. 3 is located in the No. 3 generator room at the first platform level. This arrangement separates each GTGS by at least three watertight bulkheads. This reduces the chance of loss of electric power because of battle damage.

The GTGSs can be started and monitored at the LOCOP (4) mounted on the generator housing. The LOCOP contains the electronic controls that sequence and monitor the operation of the GTE. The GTGSs can be started remotely at the corresponding switchboard. It can also be controlled at the EPCC in the CCS. Control of generator voltage, frequency, and the generator circuit breaker is available at either the EPCC or the switchboard.

Each GTGS has its own independent seawater cooling system and lube oil system (5). The module is cooled by air supplied from the intake system through an electric fan. Two fans are used on the DDG and CG classes. Support for the module includes other starting air from the bleed air (low-pressure) (6) and high-pressure air systems (7), signal air from the SSAS, emergency cooling water from the seawater service system, fuel from the engine room's FO service system, CO_2 from the fire extinguishing system, and gas turbine cleaning/rinsing solution from the water wash system. Figure 8-2 shows the interrelations of these systems to the GTGS.

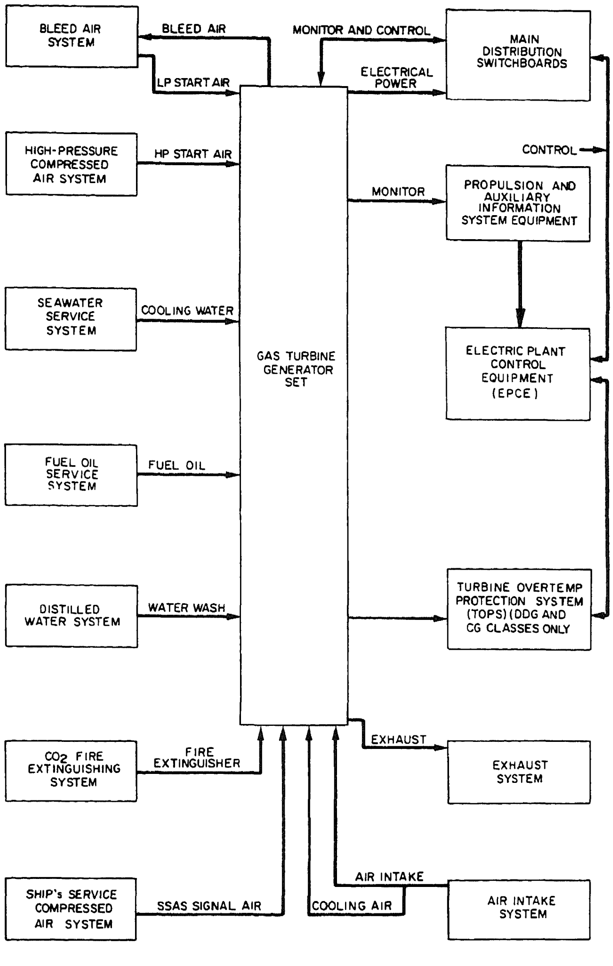

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Figure 8-2.—GTGS interrelation with ship's systems.

Service interface connections are made at the module (figure 8-3).

GTGS MODULE SYSTEMS

The module systems are used to support the operation of the engine. These systems include the base and enclosure, the water wash system, the blow-in and blow-out panels, the cooling air system, the temperature monitoring system, and the fire detection and extinguishing system.

BASE AND ENCLOSURE

The GTGS base is a steel structure attached to the ship's foundation. It is attached by twelve 5,000-pound capacity, shock/vibration isolating mounts. The base supports the entire GTGS system, except two components. One exception is the generator exciter/voltage regulator unit (including the electronic governor). The other is a remotely mounted oil cooler for the gas turbine and the reduction gear lube oil systems. The engine and the reduction gear assembly are housed in an acoustical enclosure (figure 8-4). The enclosure reduces the noise level within the machinery space and provides cooling air for the gas turbine. Barrier walls within the enclosure separate the engine compartment from the reduction gear compartment. They also form the inlet air plenum for the engine.

WATER WASH SYSTEM

Included in the enclosure is an engine water wash system (figure 8-5). The water wash system is used to clean the compressor section of the gas turbine. Two spray nozzles spray chemical cleaner or fresh water into the engine inlet while the engine

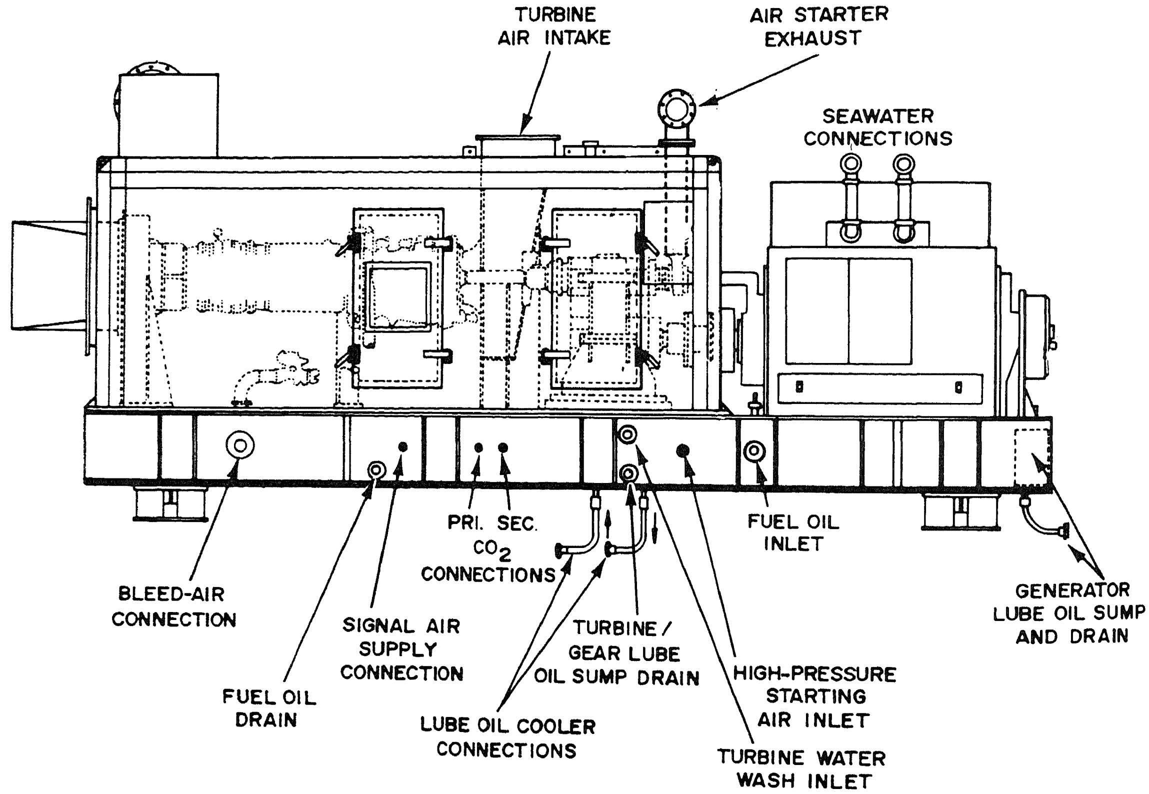

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Figure 8-3.—GTGS ship's system interface connections.

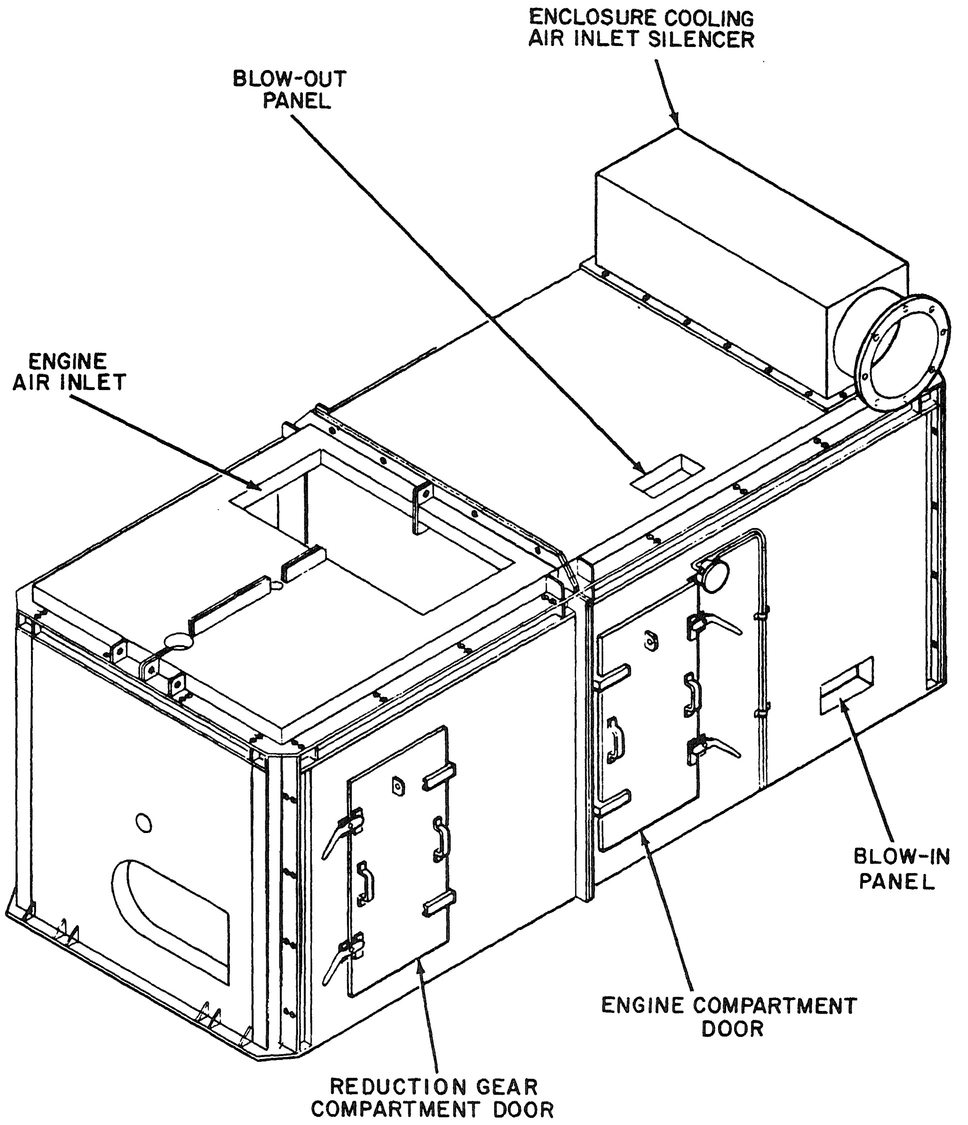

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Figure 8-4.—GTGS enclosure—right side view.

is motoring. The nozzles are mounted in the forward wall of the inlet plenum. Except for the spray nozzles and the solenoid-operated signal air valve, all components of the water wash system are ship's systems.

BLOW-IN AND BLOW-OUT PANELS

Blow-in and blow-out panels (figure 8-4) prevent damage to the module if high or low pressure occurs within the enclosure. The panels are spring-loaded in the closed position. The blow-in panel is located in the left wall of the enclosure. It is near the aft end and just above the base. The blow-out panel is located in the enclosure roof panel on the left side. It is forward of the cooling air silencer. The locations relate to an observer standing at the exhaust end looking at the intake of the module.

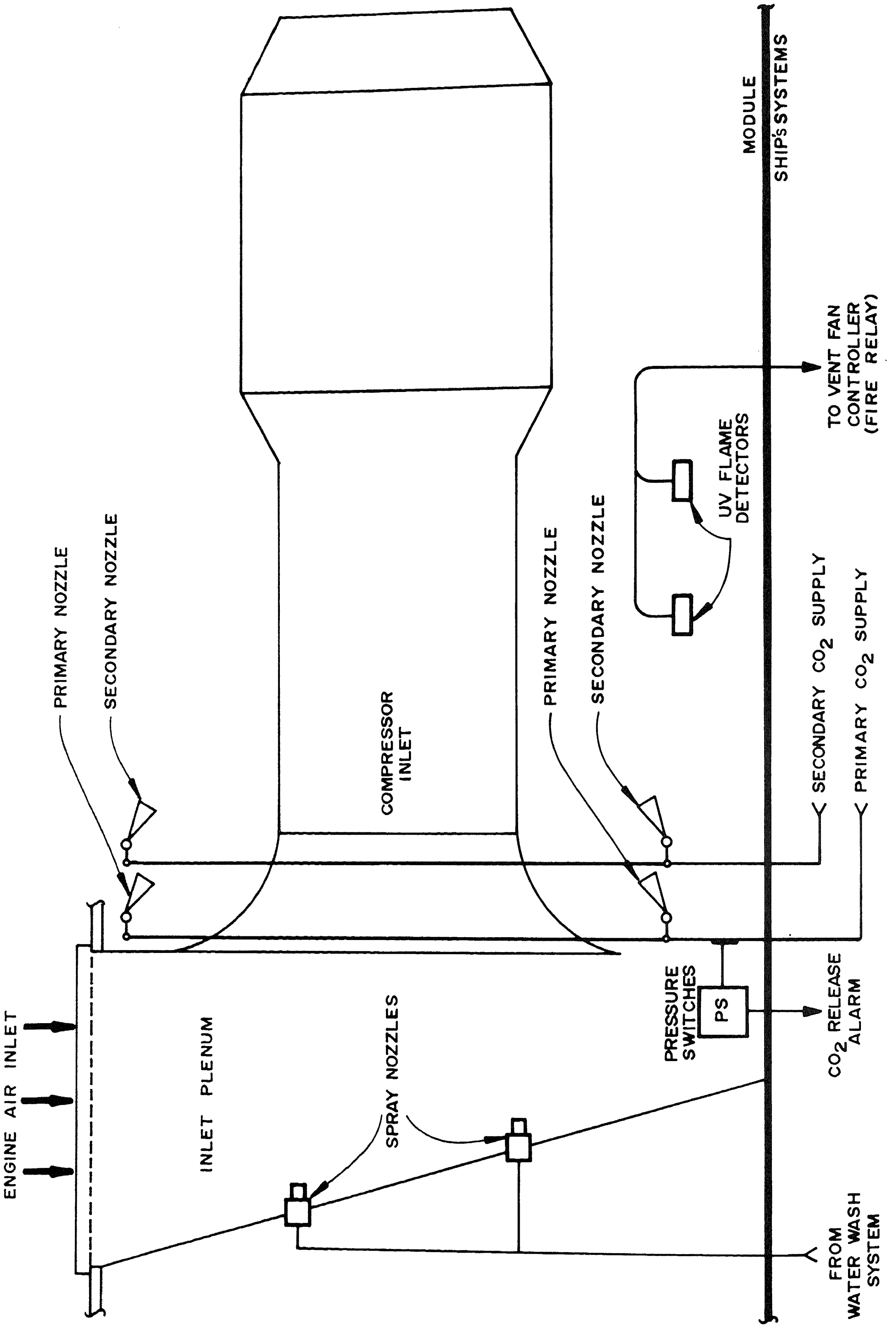

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Figure 8-5.—GTGS water wash and CO_2 systems.

COOLING AIR SYSTEM

Cooling air, extracted from the gas turbine intake duct, flows through a louvered cooling air modulator on the Model 104. Then it flows through an axial fan (two on DDGs and CGs) and a fire damper. Finally it is ducted to the enclosure. The air enters the enclosure through a silencer mounted on the aft (exhaust) end of the enclosure roof. Enclosure ceiling-mounted baffles direct the cooling air to the forward (compressor) end of the enclosure. The air circulates around the engine. It exits through a gap between the engine exhaust nozzle and the exhaust eductor section. Then it mixes with the engine exhaust gas. The fan and the action of the exhaust eductor provide the cooling airflow required during operation.

Module Temperature Monitoring (DD-963 Class)

Two temperature switches, a thermostat, and an RTD are associated with the cooling air system. The components are located inside the acoustical enclosure. One switch controls the cooling air fan, turning the fan on at 195 °F and off at 175 °F. The second switch activates the ENCLOSURE TEMP HIGH alarm indicator at the electric plant control equipment (EPCE). It also activates the summary alarm at the associated switchboard. This occurs when the enclosure temperature reaches 200 °F. The RTD provides a continuous enclosure temperature signal to both the LOCOP and propulsion auxiliary machinery information system equipment (PAMISE). The signal in the PAMISE is used for data logging and the DDIs. The thermostat controls the operation of the louvered cooling air modulator.

Module Temperature Monitoring (CG-47 Class)

Two temperature switches, a thermostat, a manual rotary selector switch, and an RTD are associated with the cooling air system. The manual rotary selector switch is located in the LOCOP. It is a four-position switch: FAN A, FAN B, MANUAL, and OFF. When the selector switch is positioned on FAN A or FAN B, this selects the lead fan. When the LOCOP switch is positioned on MANUAL, you can select a fan by using the LOCOP pushbutton indicators. The fan selected will operate until it is stopped manually. The temperature switches work with the rotary switch to determine which is the lead fan or for manual operation. With the rotary switch in the FAN A position, the A fan will act as lead fan. When the GTG is started, the A fan will start at an enclosure temperature of 170 °F. If the temperature continues to rise, the standby fan B will start at 190 °F. It will continue to run until the temperature drops to 180 °F. When you secure the GTG, the lead fan will continue to run until the temperature drops to a point below 140 °F. In manual mode, each fan will respond to the manual START and STOP pushbuttons except when the fire alarm system is activated.

The RTD in the enclosure activates the ENCLOSURE TEMP HIGH alarm indicator at the EPCE. The RTD on the Model 139 operates like the RTD on the Model 104.

FIRE DETECTION AND EXTINGUISHING SYSTEM

The fire detection and extinguishing system has two UV flame detectors and four CO_2 discharge nozzles (figure 8-5). The flame detectors are mounted on the engine side of the inlet plenum wall. The CO_2 discharge nozzles are mounted in pairs above and below the air inlet housing. Each pair has one primary and one secondary discharge nozzle. The CO_2 is piped to the module from the primary and secondary CO_2 tank banks. When the flame detector detects a fire, an electrical signal from the vent fan controller activates the primary CO_2 system.

GAS TURBINE ENGINE ASSEMBLY

The Allison Model 501-K17 is a single shaft, axial flow gas turbine. It has a 14-stage axial flow compressor, a can-annular combustor, and a 4-stage axial flow turbine directly coupled to the

compressor (figure 8-6). The GT drives the generator through a reduction gear. The reduction gear is mounted in front of the GT. It is coupled to the compressor front shaft by a PTO shaft. The GT and reduction gear are mounted in a common shock-mounted, sound reducing enclosure. The GT is mounted on a suspension system at its approximate center of gravity. It is adjusted so minimum stress is placed on the bolted flanges of the PTO housing. This allows freedom of movement in all planes. This also maintains engine reduction gear alignment when movement occurs because of shock, thermal growth changes, and so forth. The direction of rotation of the engine is counterclockwise when viewed from the exhaust end.

AIR INTAKE

The air intake has a one-piece cast aluminum inlet housing. This forms the airflow path to the compressor. The air inlet housing (figure 8-7) has an outer case, a center hub, and eight struts

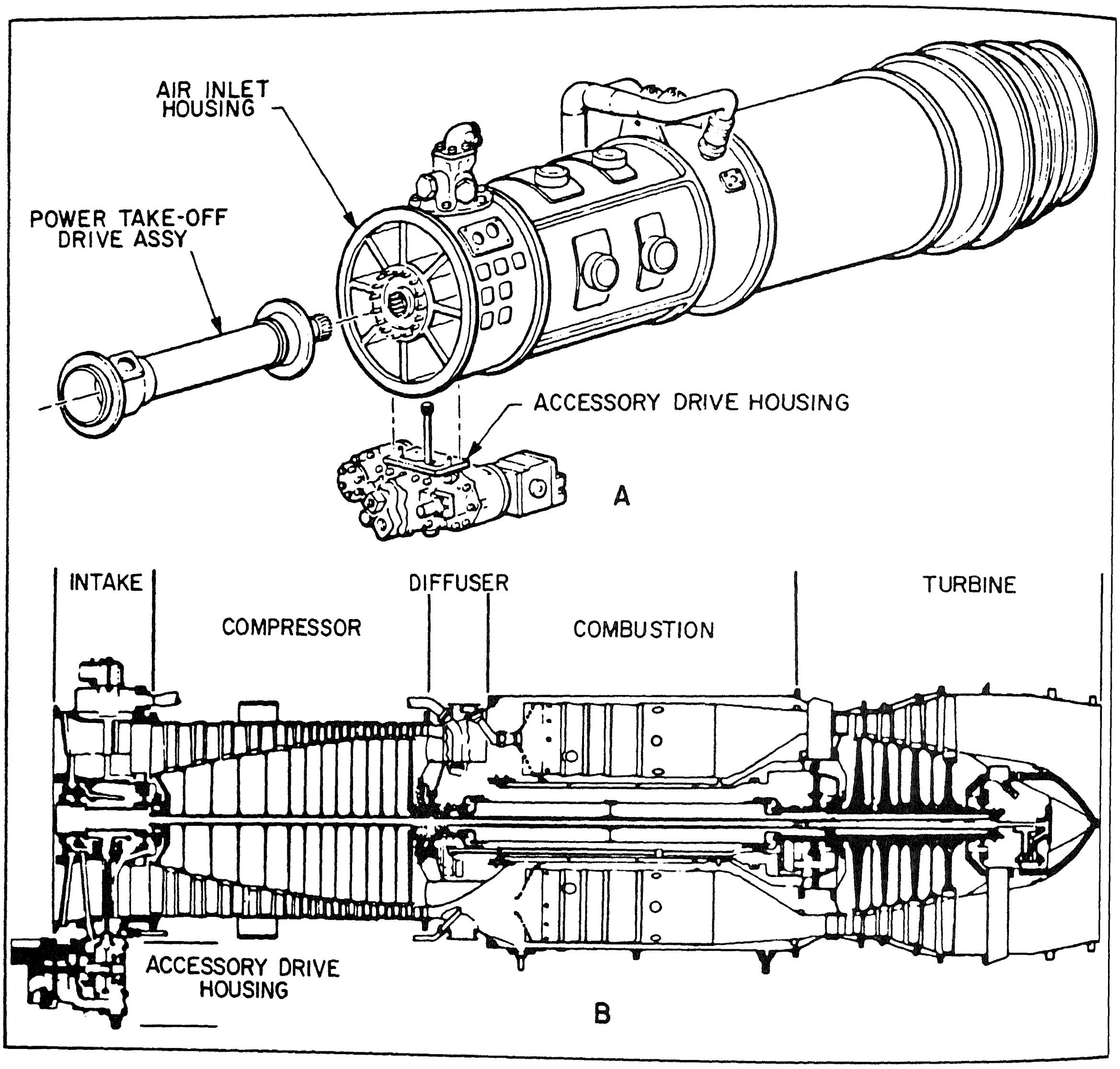

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Figure 8-6.—Allison 501-K17 gas turbine engine; (A) overall view, (B) cutaway view.

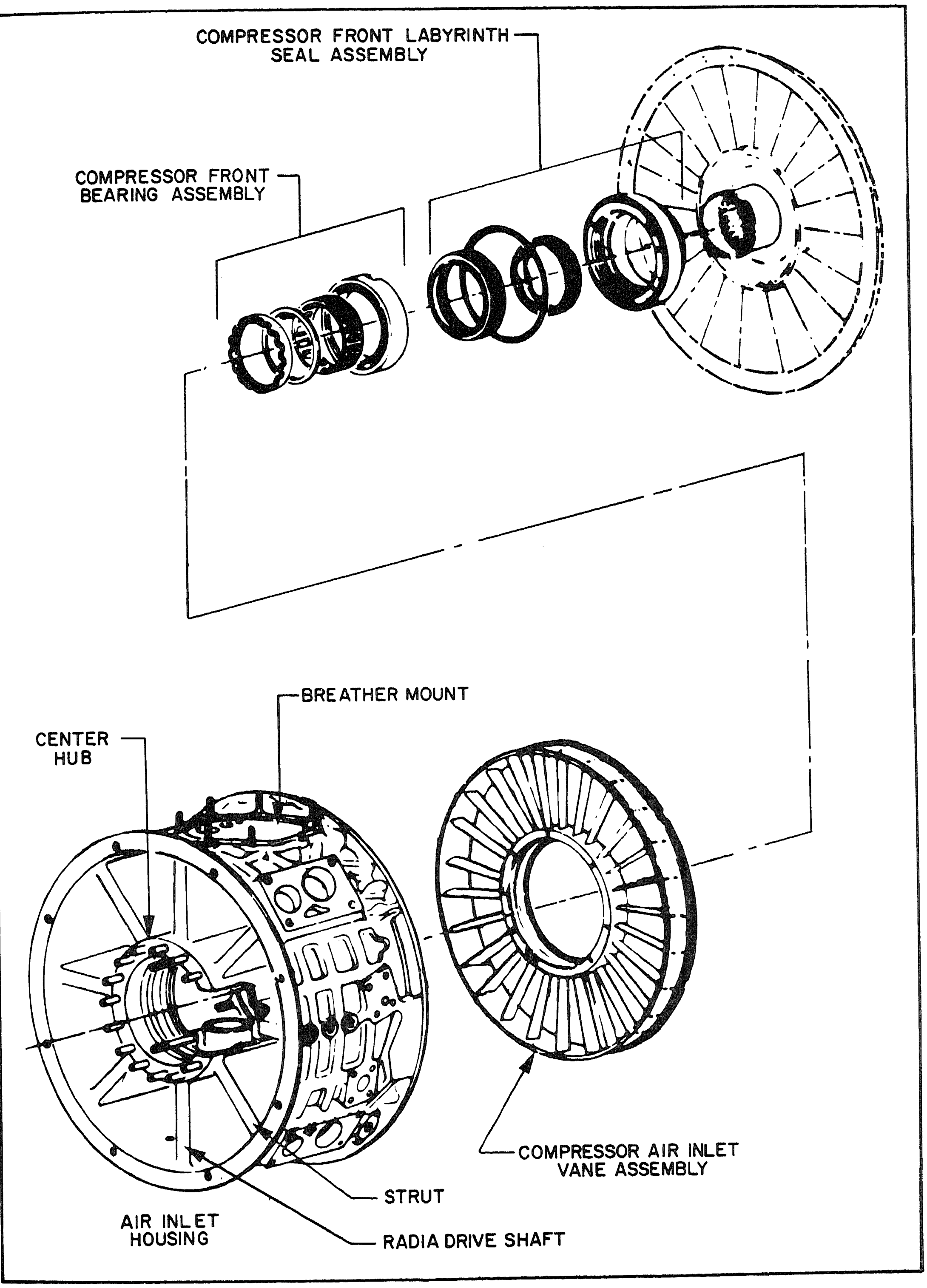

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Figure 8-7.—Air inlet housing, inlet guide vanes, and compressor front frame.

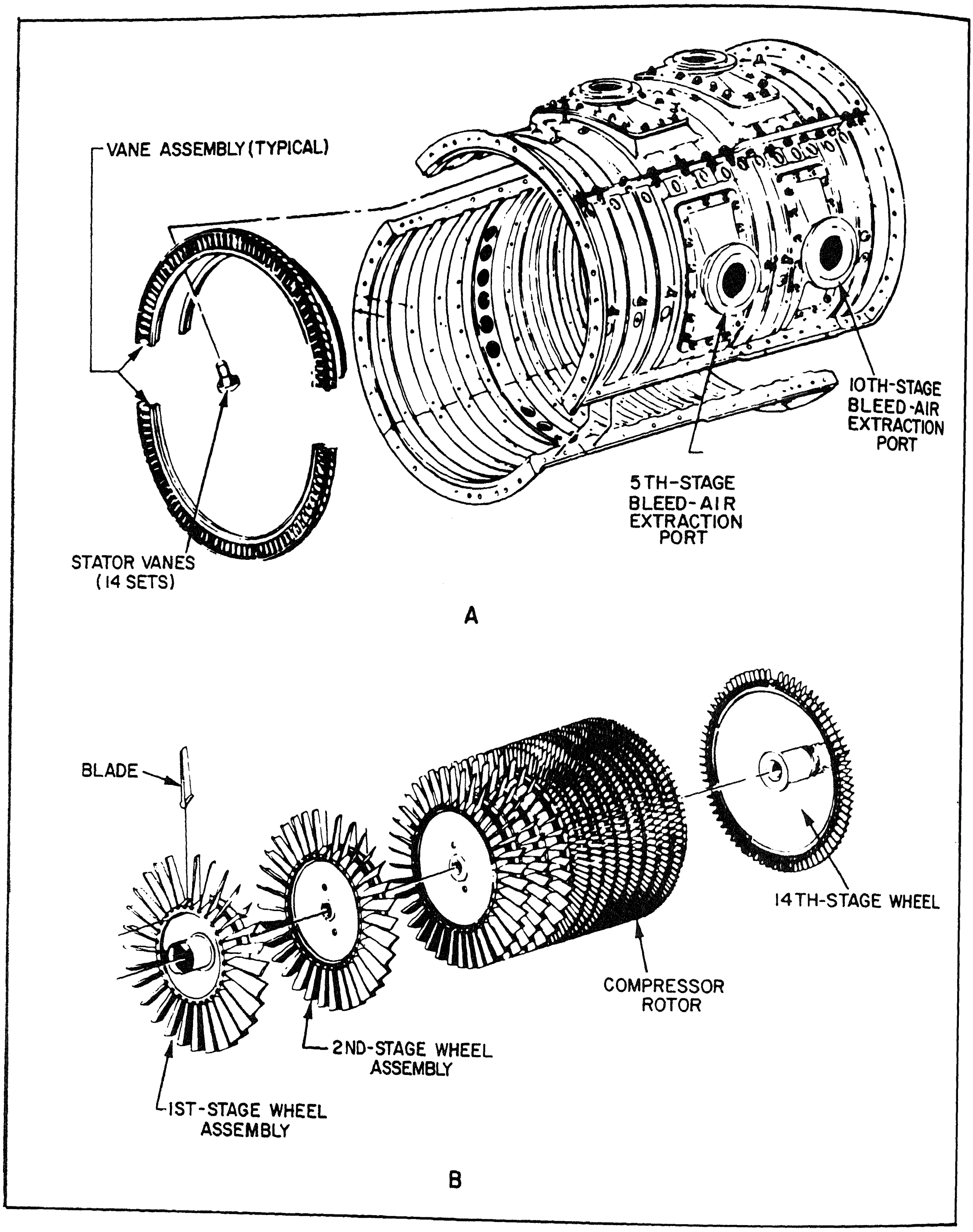

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Figure 8-8.—Allison 501-K17 compressor; (A) stator, (B) rotor.

connecting the hub to the outer case. The hub contains the compressor front bearing. This supports the forward end of the compressor rotor, the bearing labyrinth seal, and the bevel gears. These gears are required to drive the accessory gearbox. The bottom strut contains the radial drive shaft. The shaft transfers power from the compressor rotor to the accessory gearbox which is used to drive the accessories. The outer case has a pad on the bottom which provides the mounting for the accessory gearbox. The turbine breather is mounted on the top. The housing also has passages for directing anti-icing air to the strut leading edges and the IGV assembly. This assembly is located in the after side of the inlet housing. However, in this application engine anti-icing is no longer used.

COMPRESSOR SECTION

The compressor section has a compressor stator (figure 8-8, item A), a compressor rotor (figure 8-8, item B), and a diffuser (figure 8-9).

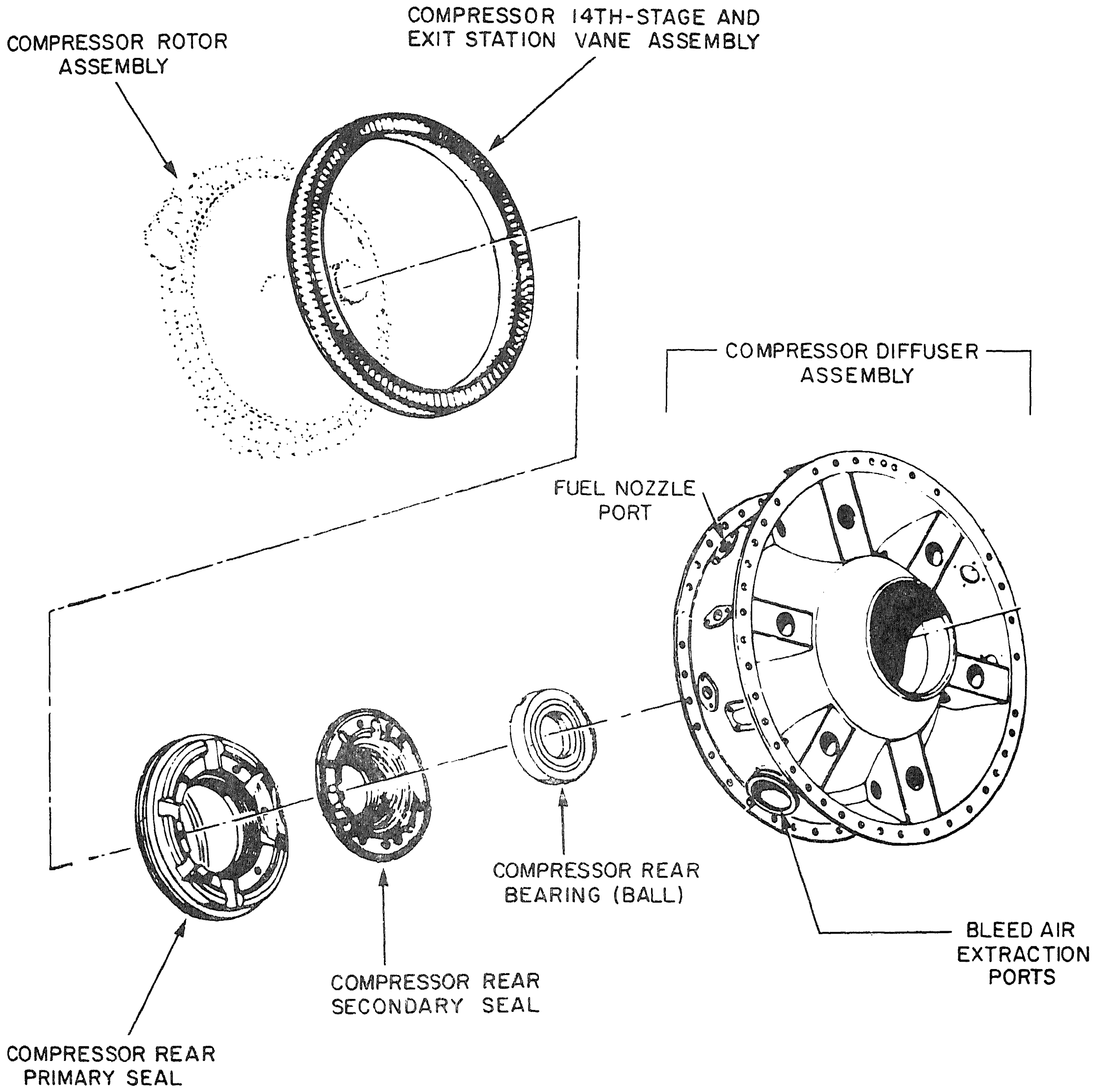

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Figure 8-9.—Allison 501-K17 diffuser and 14th-stage stator vane assembly.

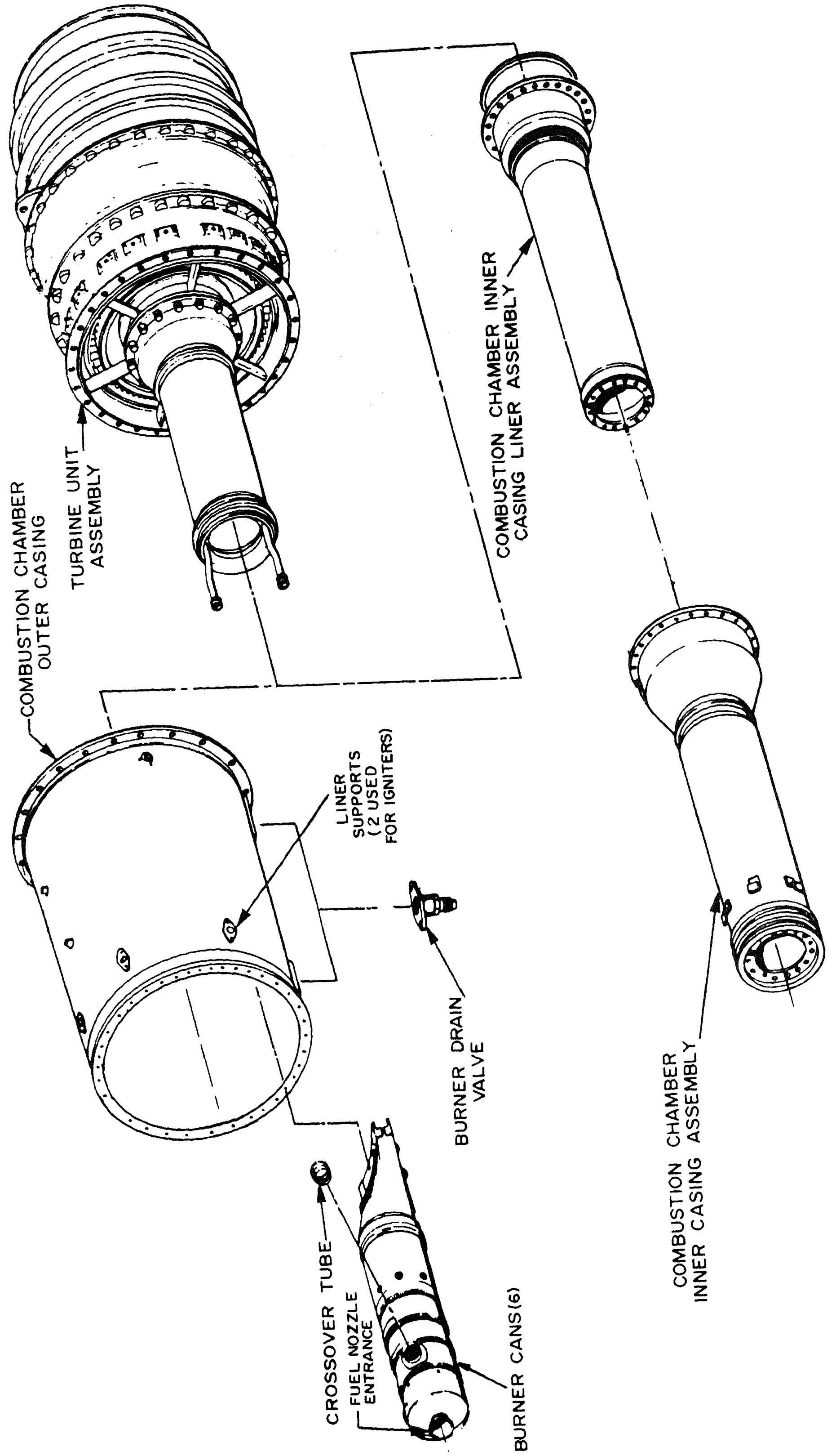

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Figure 8-10.—Allison 501-K17 combustion section.

The air inlet housing described in the preceding paragraph is also part of the compressor section. The compressor case is made up of four sections bolted together along horizontal split lines. The case contains the 14 stages of stator vanes and the exit guide vanes. The rotor is made up of 14 individual wheels. The wheels contain the 14 stages of blades and are pressed and bolted together as one assembly. The diffuser (figure 8-9) is of welded steel construction. It is used to diffuse the compressor discharge air and direct it into the combustor. The diffuser supports the compressor rear bearing/thrust bearing, the compressor seal (two-stage) stationary members, and six fuel nozzles. It also provides three bleed air extraction ports to which a manifold is attached. This allows bleed air extraction (up to 10 percent of total engine airflow) to the ship's bleed air system.

COMBUSTION SECTION

The combustion section has six individual combustion chambers (burner cans) (figure 8-10). They are equally spaced in an annulus formed by a one-piece outer casing and a two-piece inner casing. Six crossover tubes connect the burner cans. These provide flame dispersal during starting. The burner cans are held by the fuel nozzles, turbine inlet vane assemblies, spark igniters (two chambers), and liner supports (six chambers). The burner cans are of welded construction. The outer casing encloses the burner cans and provides the supporting structure between the diffuser and turbine. This casing has two drain valves to drain unburned fuel after shutdown or after a false start. These valves open when combustion pressure drops below 1 to 5 psig. They close above 1 to 5 psig on increasing pressure.

The two-piece inner casing has an inner casing and inner casing liner. These are separated by an air space and bolted together at the front. The inner casing liner has a bellows to take up thermal expansion and contraction. It is bolted to the turbine inlet casing at the rear. The aft end of the inner casing is bolted to the turbine inlet casing. The front end is supported by a sleeve in the diffuser. This provides for thermal expansion and contraction.

About 25 percent of the compressor discharge air entering the combustion section passes to the burner cans. It enters through holes and louvers and mixes with fuel sprayed into the burner cans by the fuel nozzles. The remaining air provides cooling air to the turbine.

POWER/EXHAUST SECTION

The power/exhaust section has several parts: the turbine inlet casing and front bearing support, turbine rotor, turbine front and rear labyrinth seals, turbine vane casing, turbine rear bearing support, and the turbine rear scavenge pump (figure 8-11). The turbine inlet casing and front bearing support house the first-stage vanes, the front turbine roller bearing, and the front labyrinth seal. The front bearing support is bolted to the inlet housing. The second-, third-, and fourth-stage vanes are mounted in the vane casing. The vane casing is a one-piece structure bolted between the aft flange of the inlet casing and the forward flange of the rear bearing support. The turbine rear bearing support contains the rear roller bearing. It also provides the sump for the rear bearing scavenge oil and mounting for the turbine rear scavenge oil pump. The turbine rotor has four wheels containing the turbine blades and is supported at each end by roller bearings. The turbine rotor, coupled to the compressor, extracts energy from the hot exhaust gas. It converts this energy into shaft horsepower to drive the compressor directly. It also drives the generator through the PTO shaft and reduction gear.

ACCESSORY DRIVE

The accessory drive assembly (figure 8-12) (accessory gearbox) provides mounting pads on the front and rear faces. The pads on the rear face are for the fuel pump, governor actuator, and external scavenge oil pump. Pads on the front face are for the speed sensitive valve, main oil pump, and oil filter. The speed sensitive valve is discussed later in this chapter. The accessory drive is driven by the compressor rotor extension shaft. This is accomplished by bevel gears located in the inlet housing which drive a radial shaft. The radial shaft is located in the bottommost strut of the inlet housing. It is connected to the accessory gearbox.

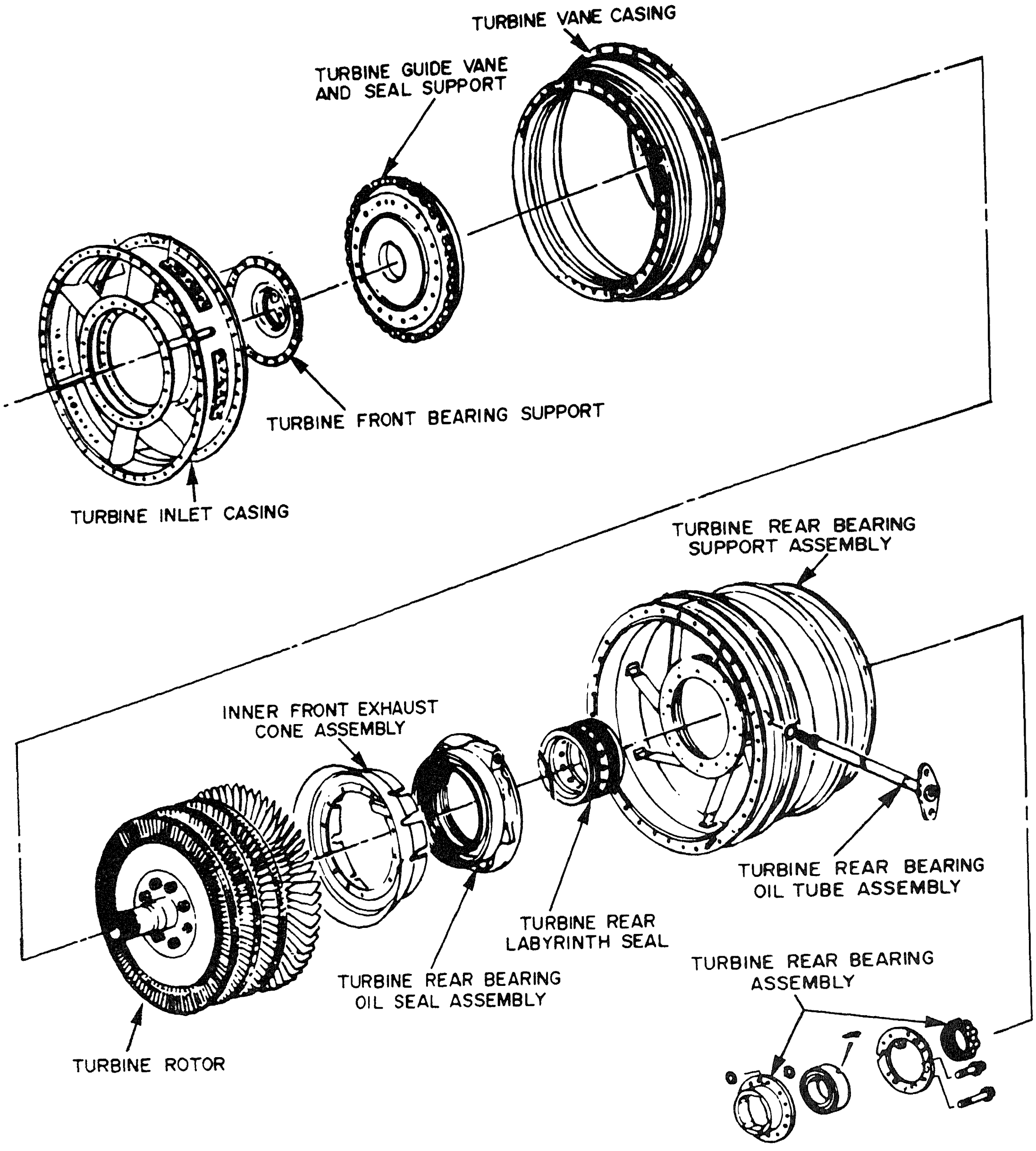

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Figure 8-11.—Allison 501-K17 turbine section.

ENGINE FUEL SYSTEM

The fuel system meters and distributes fuel to the engine. This system is used to maintain a constant rotor speed under varying load conditions. Components of the fuel system are both engine mounted and off-engine mounted.

The engine-mounted components on the Model 104 GTGS (figure 8-13) include the following parts: a dual-element fuel pump (1), a low-pressure (LP) fuel filter (2), a high-pressure (HP) fuel filter (3), a pressure relief valve (4), a liquid fuel valve (LFV) (5), an electrohydraulic governor actuator (6), a fuel shutoff valve (7), a manifold

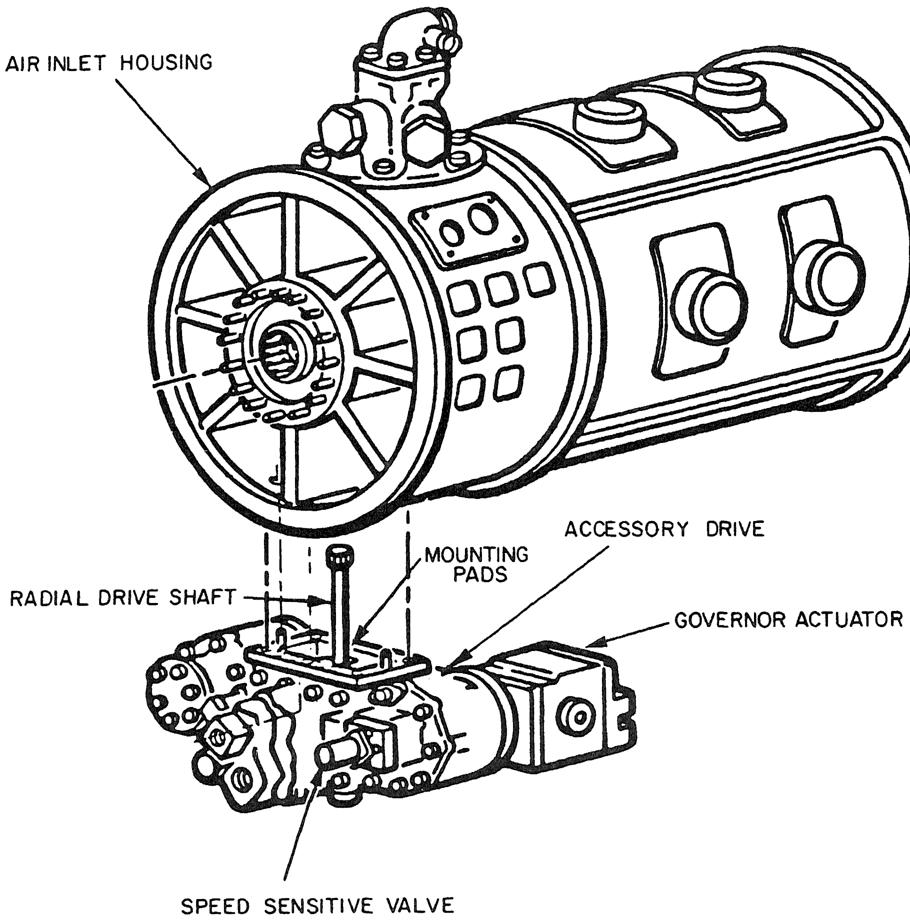

Figure 8-12.—Allison 501-K17 accessory drive section.

drain valve (8), fuel nozzles (9), and burner drain valves (10).

Off-engine mounted components of the Model 104 are a temperature biased CIT/CDP sensor (11) and a start temperature limit control valve (12). The Model 104 uses the Woodward 2301 governor control system.

The Model 139 fuel system (figure 8-14) is slightly different from the Model 104 fuel system. It does not have the fuel enrichment system found on the 104. Also the Model 139 incorporates an engine-mounted flow divider, two manifold drain valves, dual-entry type of fuel nozzles, and two fuel manifolds. Some of the Model 104 GTGSs are being converted to use these components. Refer to your ship's technical manuals for the system used on your ship. The governor system on the Model 139 is the 9900-320 governor control system. For this adaption the engine is fitted with an electrical CIT sensor, a magnetic speed pickup, and a LFV-mounted linear variable differential transformer (LVDT).

Fuel System Operation Model 104

The following paragraph is a discussion of fuel flow through the fuel system of the Model 104. Refer to figure 8-13 as we describe the operation.

Fuel from a gravity feed tank enters the enclosure and flows into the inlet of the fuel pump. It passes through the pump boost element, through the LP filter, and into the HP elements.

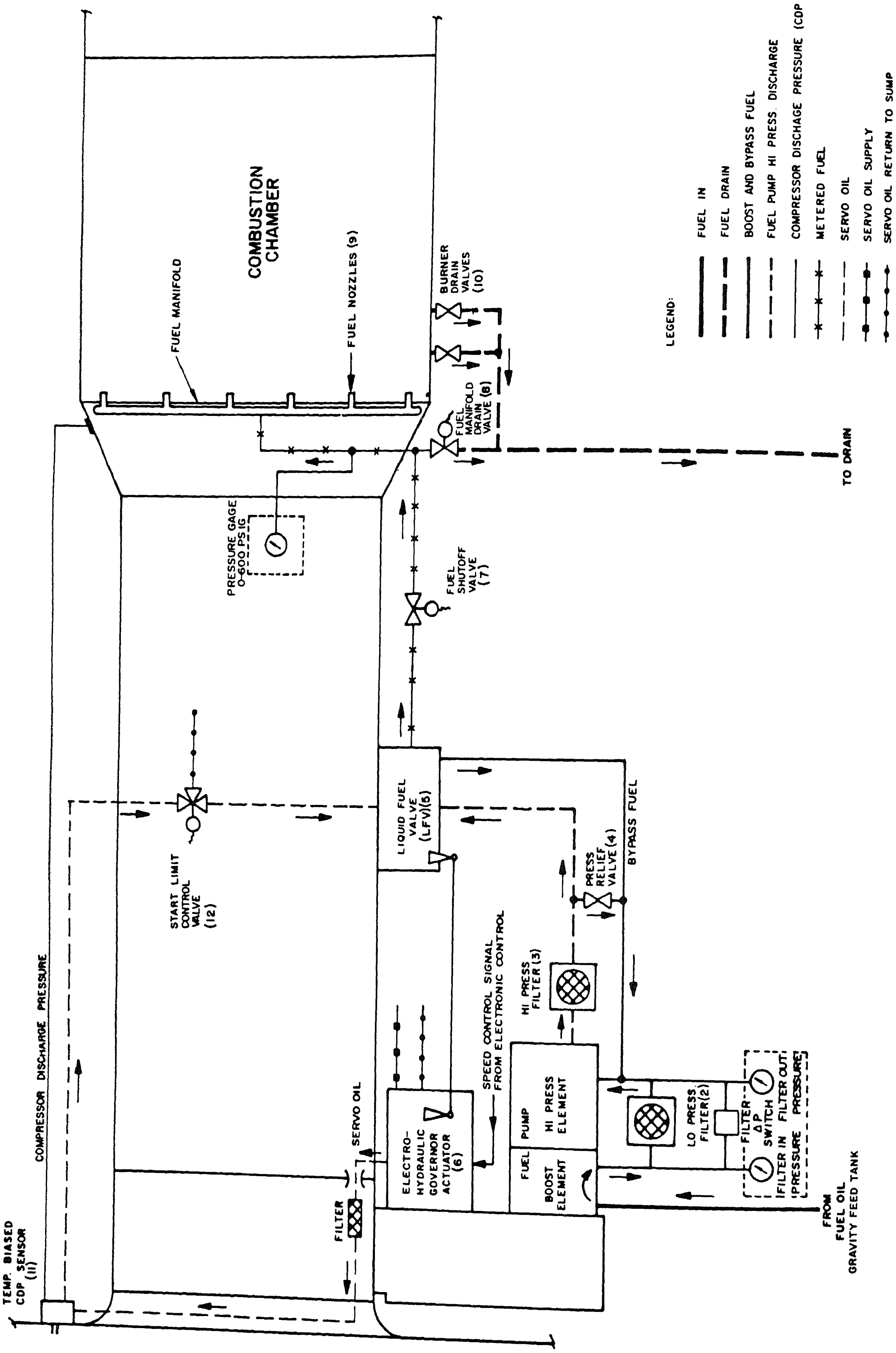

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Figure 8-13.—Model 104 fuel system.

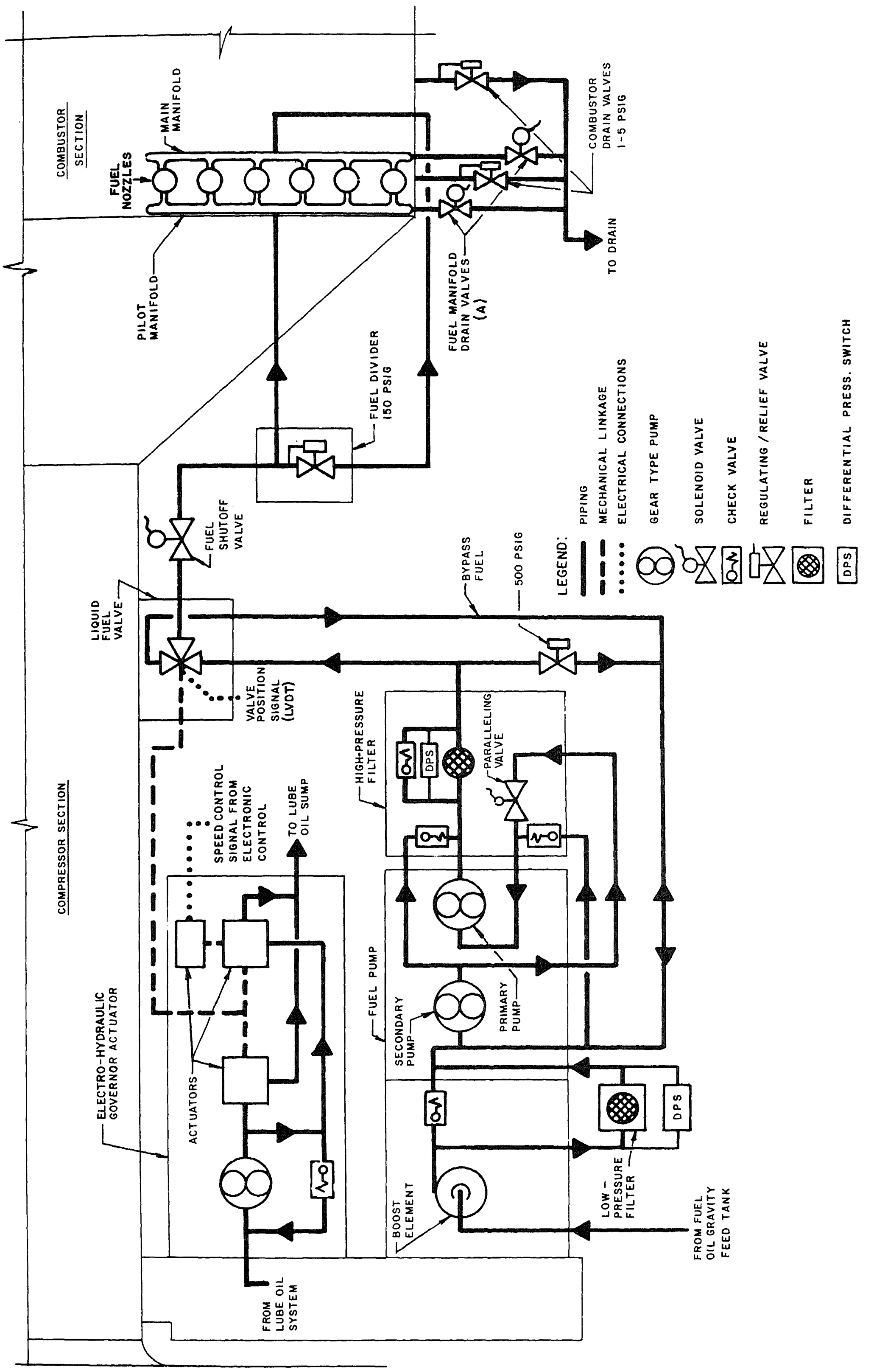

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Figure 8-14.—Model 139 fuel system.

From the pump's HP elements, the fuel passes through the HP filter and into the LFV. Metered fuel from the LFV passes through the fuel shutoff valve. It then flows through the fuel manifold to the fuel nozzles. There it is discharged into the combustion chambers. The fuel pump delivers more fuel than is required. So the LFV bypasses the excess fuel back to the inlet side of the pump's HP elements.

Fuel System Operation Model 139

Fuel system operation of the Model 139 (figure 8-14) is similar to the 104. No fuel enrich feature is available. After the fuel shutoff valve, the fuel goes to the flow divider. Some of the fuel goes directly to the pilot manifold. At 150 psig fuel is also diverted to the main fuel manifold. Two manifold drain valves are also used to drain both manifolds at shutdown. Remember, some Model 104 units have been modified to use this flow divider and dual-entry fuel nozzles.

Fuel Pump

The fuel pump (figure 8-15, item A) is an engine-driven, dual-element pump. It is mounted on the aft right side of the accessory gearbox. The boost element has an impeller-type centrifugal pump and bypass valve. The HP element has a dual-element (primary and secondary) gear-type pump.

In operation, fuel enters the pump, passes through the boost element, then flows externally

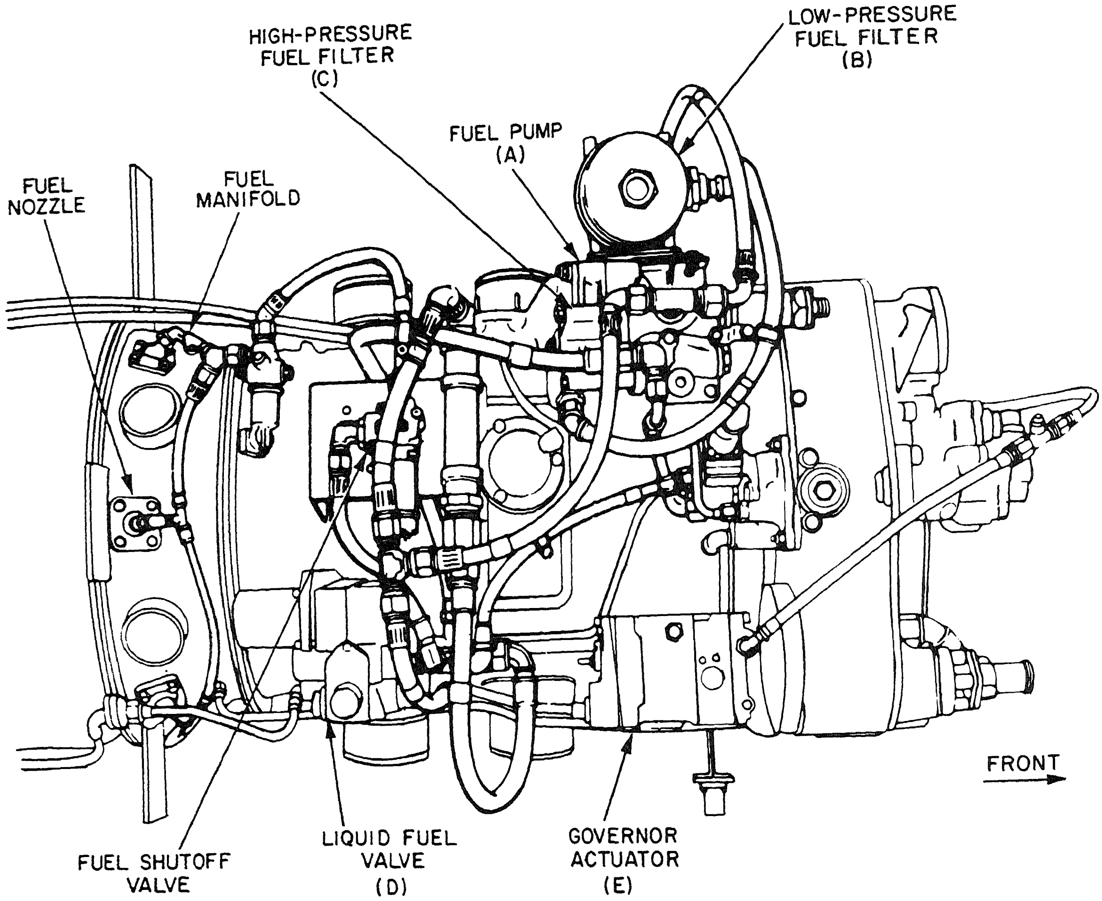

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Figure 8-15.—Fuel system components (bottom view of engine).

hrough the LP filter. It then returns to the HP elements through passages in the HP filter assembly. The bypass valve (not shown) opens only in the event of boost pump failure. Fuel normally flows in series through the secondary and primary elements of the gear pump. However, he two elements are placed in parallel from about 2200 to 8400 rpm by a solenoid-operated paralleling valve. It is located internal to the fuel pump assembly. From the HP element of the pump, fuel flows to the HP filter.

Low-Pressure Filter

The LP filter (figure 8-15, item B) is a paper cartridge type. It is located in the fuel line between the boost pump outlet and the HP element inlet. Relief valves are incorporated in the filter head to bypass the fuel if the filter becomes clogged. Low-pressure filter inlet and outlet pressures are shown on the engine gauge panel.

High-Pressure Filter

The HP filter (figure 8-15, item C) assembly s mounted on the bottom of the fuel pump. It has a filter, bypass valve, two check valves, and a solenoid-operated paralleling valve. The filter s a 33-micron disk type. It is removable for servicing. The bypass valve opens to permit continuous flow if the filter becomes clogged. If one HP gear element fails, the check valves permit engine operation from the other element.

Pressure Relief Valve

The pressure relief valve is closed during normal engine operation. If the pump discharge pressure reaches 500 ± 10 psig above bypass line pressure, the relief valve opens. This permits excess fuel to return to the pump.

Model 104 Liquid Fuel Valve

The LFV (figure 8-15, item D) is mounted on he left side of the engine. It is mechanically and hydraulically connected to the electrohydraulic governor actuator. The hydraulic connection is hrough the CIT/CDP sensor and the start emperature limit control valve. It has a metering valve, an acceleration limiter, and a bypass valve. It meters the required fuel for all engine operating conditions. The electrohydraulic governor actuator linkage and the acceleration limiter (internal part of the fuel valve) control the metering valve position. Thus they control the fuel flow. The acceleration limiter schedules fuel flow during starting as a function of CDP and CIT. During starting and rapid acceleration, the limiter overrides the governor input. This prevents compressor surge (stall) and excessive TIT. The limiter linkage (internal) is actuated by servo oil pressure from the electrohydraulic actuator. This is regulated by the CIT/CDP sensor.

To accurately meter fuel flow, you have to maintain a constant pressure drop across the metering valve. This is done when excess fuel from the pump is returned to the pump by the bypass valve.

Model 139 Liquid Fuel Valve

Like the Model 104, the Model 139 LFV is mounted on the left side of the engine. It is mechanically connected to the electrohydraulic governor actuator. It has a fuel metering valve and a fuel valve position sensor. It meters the required fuel for all engine operating conditions.

The LFV is directly controlled by the governor actuator. During start and running of the engine, the LFV is positioned by the governor to limit the amount of fuel to the fuel nozzles. The governor control circuit receives inputs of engine speed, CIT, fuel valve position, and TIT. The CDP pressure is measured by the LFV. The control circuit sets the LFV through the governor actuator. This provides the proper amount of fuel to the engine for all engine power and acceleration settings.

The fuel valve position sensor is an LVDT. It is mechanically linked to the LFV metering sleeve to sense fuel valve position. The linkage moves the sleeve to the actuator. As it does this, the amount of excitation voltage transmitted to the LVDT output is changed. The output of the LVDT is proportional to the position of the fuel metering sleeve. A comparator compares inputs from the electronic control unit and the LVDT. This is done to correctly position the fuel valve.

Excess fuel from the pump is returned to the secondary pump suction by the bypass valve. Like

the Model 104 LFV, this is done to maintain constant pressure at the metering valve.

Fuel Shutoff Valve

The fuel shutoff valve (figure 8-15) is a normally closed, solenoid-operated valve. It is located in the line between the LFV and the fuel manifold. All fuel to the fuel nozzles must pass through this valve. During the starting cycle, the valve is opened (energized) by the electronic speed switch circuit at about 2200 rpm. The valve is closed by the control circuits to shut down the engine.

Fuel Manifold Drain Valve

The fuel manifold drain valve is a spring-loaded, solenoid-operated valve located at the bottom of the manifold (figures 8-13 and 8-14, items A). It drains the fuel from the manifold to the waste oil drain tank during coastdown. The valve is open (energized) only during the 2-minute period determined by the coastdown timer. Two manifold drains are used on units with the dual-entry fuel nozzles. On the Model 139 these valves are open any time the engine is below 2200 rpm.

Electrohydraulic Governor Actuator

The electrohydraulic governor actuator is engine driven. It is mounted on the left side of the accessory gearbox (figure 8-15, item E). Its output shaft is mechanically linked to the LFV. It receives signals from the electric governor (EG) control box and positions the LFV. The LFV, in turn, meters fuel to the engine. The governor actuator incorporates normal control by the EG system and backup control by a centrifugal governor. Each are alone able to position the output shaft.

An integral oil pump provides servo oil pressure for governor operation as well as other functions. Engine lube oil pressure from the accessory gearbox is supplied to the actuator pump through an external line. During normal operation, an output signal from the EG control box produces a force on an armature magnet. The magnet is attached to a pilot valve plunger and moves the plunger up or down. The pilot valve plunger directs servo oil pressure to change the position of the output shaft. If the electrical signal to the governor actuator is interrupted, it may attempt to overspeed the engine. If this happens, the pilot valve plunger and terminal shaft will be positioned toward the maximum fuel flow position. When the engine speed exceeds the preset limit, the centrifugal governor will assume control of the engine. Flyweights, opposed by speeder spring force, position the pilot valve plunger as a function of engine speed. The pilot valve plunger directs servo oil pressure to position the output shaft connected to the LFV. The centrifugal governor is set to regulate engine speed at about 480 to 580 engine rpm above the normal electric governor operating speed. It has been factory adjusted between 14,300 to 14,400 rpm. This equals between 62- to 62.5-Hz generator output.

Model 104 GTGS CIT/CDP Sensor and Start Temp Limit Control Valve

The CIT/CDP sensor senses both CIT and CDP. It regulates servo oil from the electrohydraulic governor to the acceleration limiter in the LFV in relation to CIT and CDP. The acceleration limiter, in turn, schedules fuel flow as a function of CIT and CDP. During the start cycle above 2200 rpm and during rapid accelerations, the acceleration limiter overrides the input from the electrohydraulic governor. This limits the maximum fuel flow and prevents compressor stall and/or excessive TIT. Below 2200 rpm, the regulated oil pressure from the CIT/CDP sensor is blocked by the start temperature limit control valve. This assures the turbine starts on the minimum fuel flow at lightoff. The CIT/CDP sensor is mounted on the inlet air plenum. The temperature sensing element protrudes into the inlet airstream.

The start limit control valve is a normally open, three-way, solenoid-operated valve. It is located in the regulated servo oil supply line between the CIT/CDP sensor and the LFV (figure 8-13). During the start cycle below 2200 rpm, the valve is energized. This blocks the regulated oil supply and ports the oil from the acceleration limiter (part of the liquid fuel valve) to drain. This causes the fuel valve to remain against the minimum fuel flow stop until the engine reaches 2200 rpm. Between 2200 and 12,780 rpm, the valve is normally de-energized (open). However,

if TIT exceeds 1500 °F, the valve is intermittently energized/de-energized until temperature drops below 1500 °F. Above 12,780 rpm, the valve is electrically locked out of the system (de-energized).

Model 139 CIT Sensor

The CIT sensor monitors the ambient air temperature. It applies an input reference signal to the speed correction and acceleration temperature reference circuits in the electronic fuel control system. Speed correction is the voltage from the speed frequency sensor corrected by the CIT. This results in increased fuel as CIT decreases. CIT bias is used during all evolutions of engine operation. The CIT sensor is mounted on the inlet air plenum. The temperature sensing element protrudes into the inlet airstream.

Model 104 Fuel Manifold and Nozzles

The fuel manifold has sections of steel-braided hose that connect the six fuel nozzles together. The sections of hose also connect the nozzles to a drain valve at the bottom of the engine. Fuel output from the fuel shutoff valve is also connected to the manifold. The fuel nozzles are air blast type. They have the following parts: a body holder, filter screen, filter screen spring, check valve assembly, a pressurized spray tip, and an air blast shroud. When fuel manifold pressure is about 150 psig or less, the fuel flow is through the pressurized spray tip. This creates a spray pattern for starting and for stable combustion at low engine speeds. When fuel manifold pressure exceeds about 150 psig, the check valve opens. Fuel then flows through the main orifices, diagonally outward from the air blast shroud swirlers. The fuel mixes with compressor discharge air flowing from the swirlers to form a finely atomized fuel spray pattern.

Model 139 Flow Divider, Fuel Manifold, and Fuel Nozzles

Fuel flow from the fuel shutoff valve is directed to the manifolds by the flow divider. The divider has an internal pressure-actuated valve. The flow divider, during start-up, allows fuel to be supplied to only the pilot manifold. When fuel pressure reaches about 150 psig, the valve opens. This allows fuel to be supplied to the main manifold.

Two fuel manifolds, pilot and main, supply fuel to the six fuel nozzles. Both manifolds are Teflon-lined hoses with braided steel armor. Each manifold is fitted with a solenoid-operated drain valve at its bottom. The pilot manifold receives fuel from the flow divider during start-up and normal operation. It distributes the fuel to the pilot connection on each of the nozzles. The main manifold receives fuel from the divider only after the pilots have been ignited. After fuel pressure from the control valve is at about 150 psig, fuel is supplied to the main connection of each fuel nozzle. The six nozzles are positioned to extend into their respective combustion liners. This is the optimum location for fuel/air mixing and combustion. Fuel from the pilot manifold flows through the center hole in the top of each nozzle. This forms a spray pattern in the combustion liner. Main manifold fuel is supplied to the holes in the periphery of the nozzle tip. From there it is sprayed into the combustion liner and mixed with compressor air for combustion.

Some Model 104 GTGSs are fitted with modification kits. They allow use of the external flow divider and dual-entry fuel nozzles. Consult your ship's technical manuals for the design used on your ship.

ENGINE LUBE OIL SYSTEM

The lubrication systems on the Model 104 and Model 139 are almost identical. The engine receives lube oil from the GTGS reduction gear lube oil system.

The engine and reduction gear lube systems share a common supply tank, filter, and cooler. The supply tank is the reduction gear sump, while the filter is base mounted inside the reduction gear section of the enclosure. The oil cooler is mounted

remotely under the module (figure 8-16). Synthetic oil, MIL-L-23699, is used in this system.

The engine lube system is a low-pressure, dry sump system. It incorporates the following components: a combination lube and scavenge pump (1), an external scavenge pump (2), a turbine scavenge pump (3), a pressure regulating valve (4), an oil filter and check valve (5), a filter bypass valve (6), and a scavenge pressure relief valve (7).

In operation, oil from the reduction gear sump (supply tank) is picked up by the reduction gear supply pump. It then flows through the supply filter and through the oil cooler. Oil from the cooler supplies both the reduction gear and engine lube oil systems. Oil to the engine flows through a regulating valve and into the inlet of the engine lube pump. From the engine lube pump, the oil flows through a filter and check valve. It then flows through drilled and cored passages and internal and external lines to areas of the engine needing lubrication.

Scavenge oil is collected by the scavenge element of the main lube and scavenge pump, the external scavenge pump, and the turbine scavenge pump. Oil from the turbine scavenge pump flows through drilled passages and internal lines to the accessory gearbox. There it is picked up by the scavenge element of the main pump. Flow from the external scavenge pump joins the flow from the main scavenge pump. This is through external lines and is returned to the reduction gear sump. The magnetic drain plugs (not shown) are on the bottom of the accessory gearbox and the discharge of the main scavenge pump. These collect any steel particles in the oil.

Main Pressure and Scavenge Oil Pump

The main pressure and scavenge oil pump assembly is mounted on the front of the accessory gearbox. It has two gear-type pumps, one each for the supply and scavenge systems. It also has a pressure regulating valve. Oil is pumped by the pressure (supply) element of the pump to the following components: the compressor extension shaft bearing, the PTO shaft midbearing, the accessory gearbox, the engine four main bearings, and the electrohydraulic governor actuator. The main shaft splines are lubricated by the oil returned by the rear turbine scavenge pump. The scavenge element picks up scavenge oil in the accessory gearbox. The oil has gravity drained from the compressor extension shaft bearing and the compressor front bearing. The scavenge element returns the scavenge oil, along with the oil from other scavenge pumps, to the reduction gear sump. An indicating type of magnetic plug is located in the scavenge side of the pump.

Oil Filter

An oil filter is mounted on the front of the accessory gearbox. It has a pleated-type element and incorporates a Teflon-seated, poppet-type check valve. This valve prevents oil from draining into the engine when the engine is shut down. A bypass valve, located in the accessory gearbox front cover, opens at a specific pressure differential. This bypasses the filter if it becomes clogged.

External Scavenge Pump

The external scavenge pump is a three-gear, dual-element pump. It is mounted on the aft side of the accessory gearbox. It scavenges the oil from the compressor rear bearing sump and from the turbine forward bearing sump. The oil from the pump is combined with the scavenge oil from the main scavenge pump. It is then returned to the reduction gear sump.

Turbine Scavenge Pump

The turbine scavenge pump is a gear-type pump. It is mounted in the rear turbine bearing support assembly. A splined coupling drives the turbine-to-compressor tie bolt. The pump scavenges oil from the turbine rear bearing and returns it to the accessory drive housing. It is covered by a thermal insulation blanket and the exhaust inner cone.

Vent System

The air inlet housing cavity and accessory gearbox are vented. This is through an external line to a breather mounted on top of the air inlet housing. Seal leakage air from the compressor rear bearing seal is vented through the two

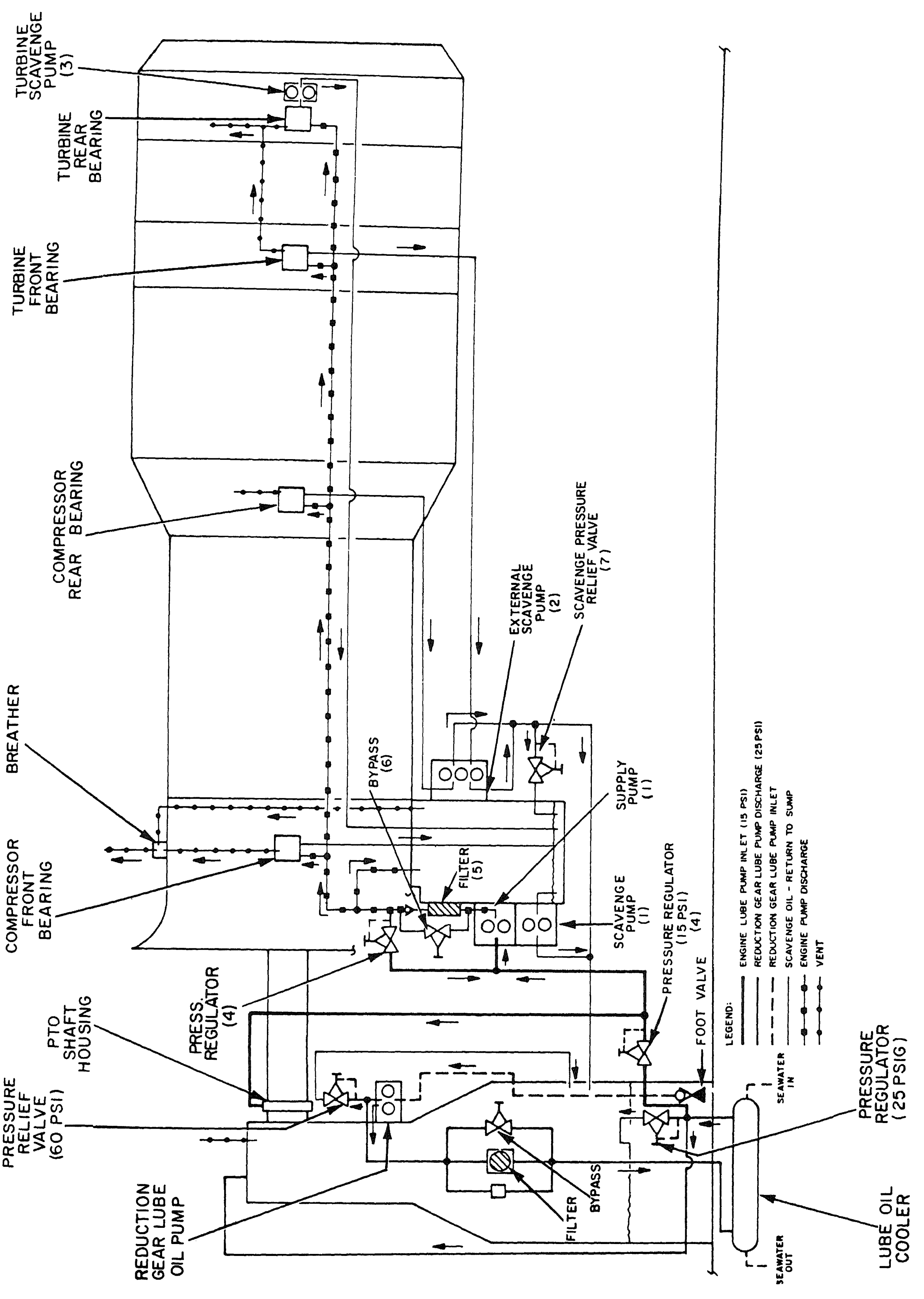

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Figure 8-16.—GTGS synthetic lube oil system.

horizontal struts of the compressor diffuser. The combustor inner casing is vented to atmosphere through two horizontal struts in the turbine inlet casing. The combustion inner casing liner is used to provide a passage for down the shaft venting. This flows through holes in the turbine coupling shaft. From there it flows to and pressurizes the turbine rear bearing labyrinth seal up to the rear face of the turbine fourth-stage wheel to enter into the exhaust gas stream.

IGNITION SYSTEM

The ignition systems of the two types of GTGSs are identical. The ignition system (figure 8-17) has an ignition exciter, high-tension leads, and two spark igniters. The system operates on +28 volts d.c. However, proper operation can be obtained over a range of +14 to +28 volts d.c. Power is supplied to the system through an electronic speed switch actuated relay. This energizes the system at 2200 rpm and de-energizes at 8400 rpm during the starting cycle.

Ignition Exciter

The ignition exciter is a sealed unit mounted on the right side of the compressor. It is a high-voltage, capacitor-discharge type of exciter. It is

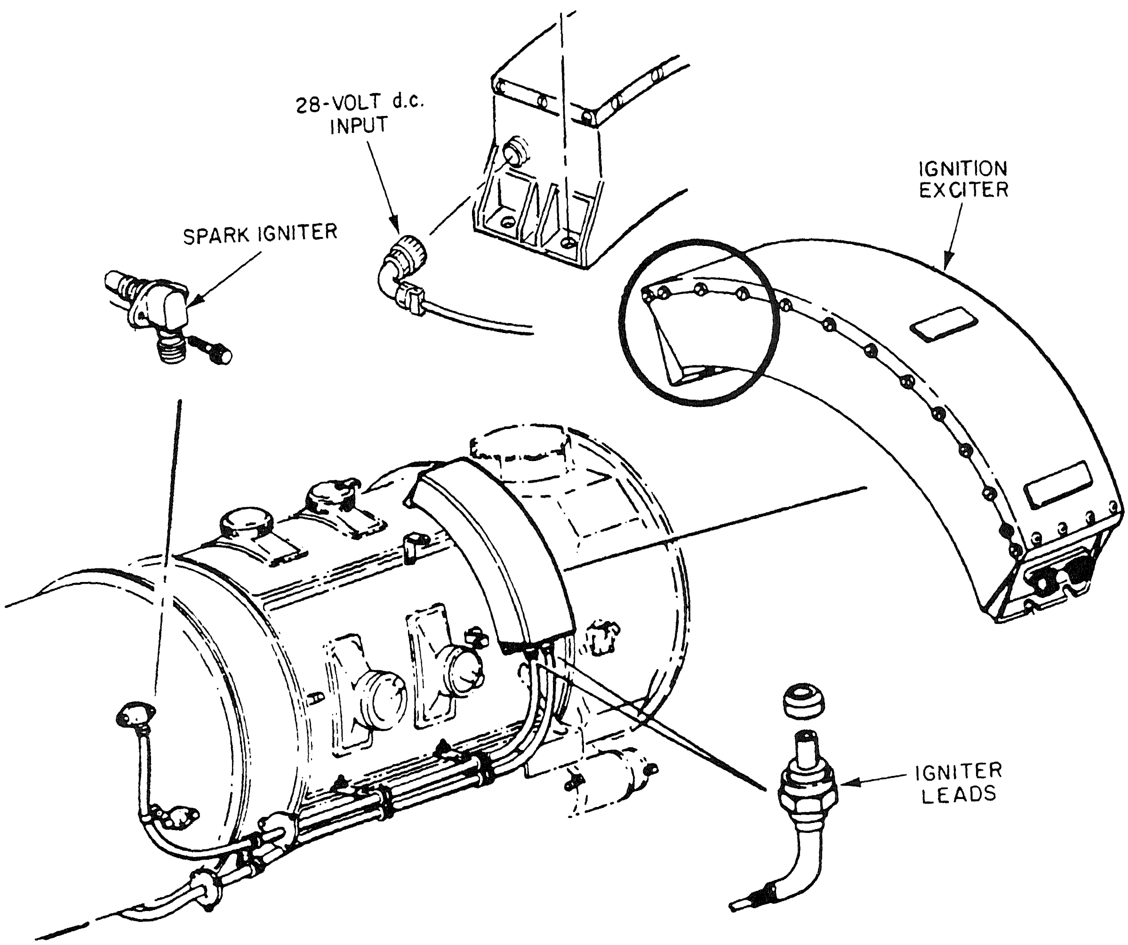

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Figure 8-17.—Igniter system components.

capable of firing two spark igniters at the same time.

Spark Igniters

The two spark igniters are mounted in the outer combustion case. One is in the No. 2 can and one in the No. 5 can. The igniters receive the electrical output from the ignition exciter. They discharge this electrical energy during starting to ignite the fuel-air mixture in the combustion cans. Two high-voltage leads connect the spark igniters to the ignition exciter.

BLEED AIR SYSTEM

The bleed air systems (figure 8-18) on the Model 104 and Model 139 are nearly identical. The only major difference is found in the 14th-stage bleed air valve. One of the features of the turbine overtemperature protection system (TOPS) is to give a surviving GTGS (assuming a casualty occurs to one GTGS while two units

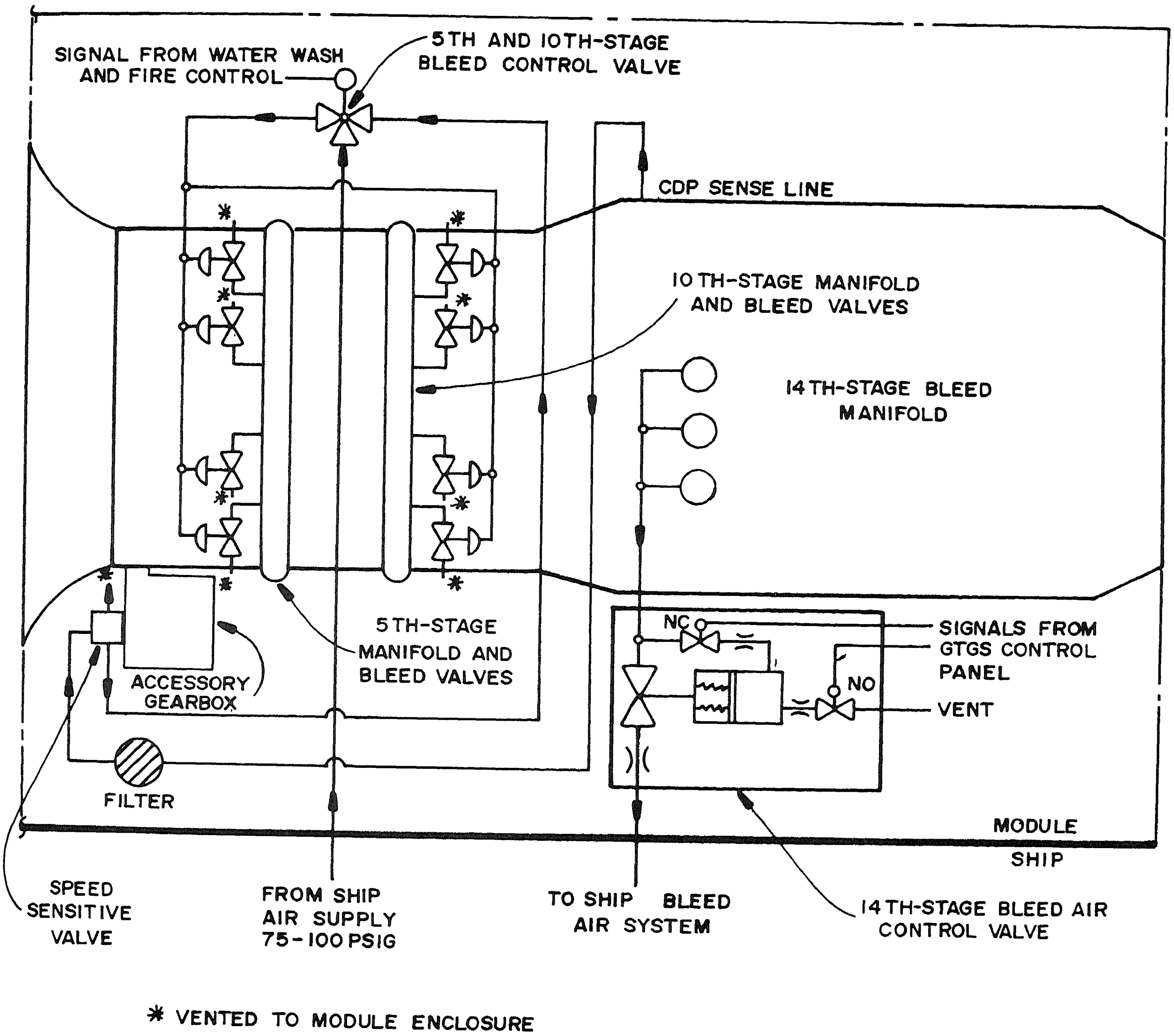

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Figure 8-18.—Allison 501-K17 bleed air systems.

are in parallel) the chance to develop more power quickly. Therefore, a fast-acting 14th-stage bleed air valve is used on the Model 139. Note that use of bleed air drains about 10 percent of the available horsepower from a running GTGS.

This GTGS loss is compensated for by quickly closing (in about 150 milliseconds) the 14th-stage bleed air valve on the surviving GTGS. Thus the engine is able to respond to transient load conditions brought about by failure of one of two GTGSs operated in parallel.

The bleed air system is two independent systems—the 14th-stage system and the 5th- and 10th-stage system. The 5th- and 10th-stage bleed air system unloads the compressor. This reduces the possibility of compressor surge during the starting cycle. The 14th-stage bleed air system extracts air from the compressor for the ship's bleed air system. Airflow up to 2.37 lb/sec at 55 to 60 psig may be extracted. This is about 10 percent of compressor airflow.

Fourteenth-Stage Bleed Air System

Fourteenth-stage compressor discharge air is extracted from ports on the compressor diffuser. It is manifolded and piped to a bleed air control valve and into the ship's bleed air system. The control valve receives a signal from the LOCOP. This signal prevents the engine from being overloaded during combined operation of bleed air and generator loading. If the TIT reaches 1870 °F, the bleed air control valve will close and maintain the TIT in the range of 1850 °F to 1870 °F. A manual switch, 14TH-STAGE BLEED, is located on the LOCOP. It allows you to enable the bleed air control circuit. When this switch is in the ON position, the bleed valve will open at 12,780 rpm. It is then fully automatic with respect to TIT. The 14th-stage bleed air valve will also close when the engine speed drops below 12,780 rpm.

The Model 139 LOCOP bleed air selector switch also has a remote position. When the switch is placed in remote, the control of the 14th-stage bleed air valve is transferred to a control panel in CCS.

Fifth- and Tenth-Stage Bleed Air System

This system has eight pneumatically operated bleed air valves, a speed sensitive valve, a filter, and a solenoid valve. Four bleed air valves are mounted on both the 5th- and the 10th-stage bleed manifolds. These valves are piston-type valves, with 5th- and 10th-stage air pressure on the inboard side of the valve. Either atmospheric pressure or 14th-stage air pressure is on the outboard side. The speed sensitive valve is engine driven. It is mounted on the forward side of the accessory gearbox. The valve has three ports. One port is piped to 14th-stage air. One port is piped to the outboard side of the 5th- and 10th-stage bleed air valves. The third port is vented to atmosphere. During operation at engine speeds below about 12,700 rpm, a pilot valve in the speed sensitive valve blocks 14th-stage air. The outboard side of the 5th- and 10th-stage bleed air valves are vented to atmosphere. Since 5th- and 10th-stage air pressure is greater than atmospheric pressure, the valves open and vent air from the compressor. At engine speeds above about 12,700 rpm, the pilot valve closes the vent port. Fourteenth-stage air is then ported to the outboard side of the bleed air valves. Since 14th-stage air pressure is greater than 5th- and 10th-stage air pressure, the valves close and bleed air is stopped. The filter is located in the 14th-stage air line to the speed sensitive valve. It prevents contaminants in the air from clogging the valve. The solenoid valve is located in the line between the speed sensitive valve and the bleed air valves. It uses ship's service air to hold the 5th- and 10th-stage bleed air valves closed during a fire stop. It also holds the valves closed while water washing the engine.

ENGINE INSTRUMENTATION

Besides the instruments that measure pressure and temperature of the engine's systems and enclosure, several sensors monitor the engine itself. These are the thermocouples, magnetic speed pickup, and the vibration sensor.

The thermocouples are wired in parallel to provide an average TIT signal. This is amplified by the turbine speed temp box in the LOCOP. This signal provides TIT indication and engine emergency shutdown functions. The speed temp

box uses the magnetic speed pickup signal for speed sensing and control during start-up. An alarm and automatic shutdown are provided for an overspeed and underspeed. The speed temp box also transmits a speed and temperature signal for remote display of engine speed and temperature on DDIs. Refer to chapter 3 of this text, Indicating Instruments, for more information about these sensors.

Thermocouple System

There are 18 dual-element, Chromel-Alumel thermocouple probes mounted on the turbine inlet casing. The probes extend into the outlet of the combustion liners at the turbine inlet. Each of the probe elements is independent of the other, thereby providing two independent sampling circuits. The thermocouple probe housing leading edges are air cooled to prolong probe life. To accomplish this, cooling air enters the probe cavity leading edge through a hole below the probe shoulder. It flows through the probe and is discharged through two small openings in the bottom of the probe.

A thermocouple harness assembly has a right and a left section. It is enclosed in channels that are rigidly mounted on the turbine inlet case forward flange. The harness incorporates separate leads for each thermocouple probe. A terminal block serves as the junction for two thermocouple harnesses and the amplifier leads. It has eight terminal connections and four terminals for each of the two harnesses.

Vibration Transducer

Engine vibration is measured by a single displacement type of vibration transducer. It is mounted on the turbine rear bearing support at the 12 o'clock position.

Speed Pickup

Engine speed is measured by a magnetic pickup. This is mounted in the PTO shaft housing over the shaft exciter teeth. Passage of the exciter teeth under the magnetic pickup produces electrical impulses. These impulses are used by the speed temp box for speed sensing. This, in turn, is used for start sequencing, over- and underspeed protection, and monitoring.

POWER TAKE-OFF ASSEMBLY

The PTO assembly has a PTO shaft, shaft adapter, midbearing assembly, housing, and speed sensor pickup (figure 8-19). The assembly

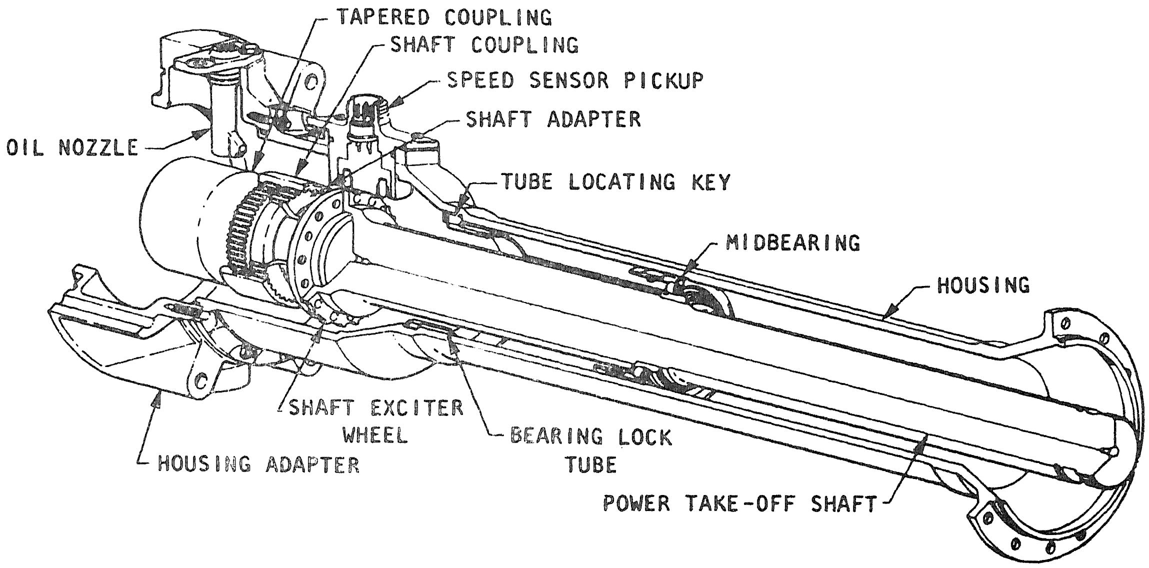

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Figure 8-19.—Power take-off assembly.

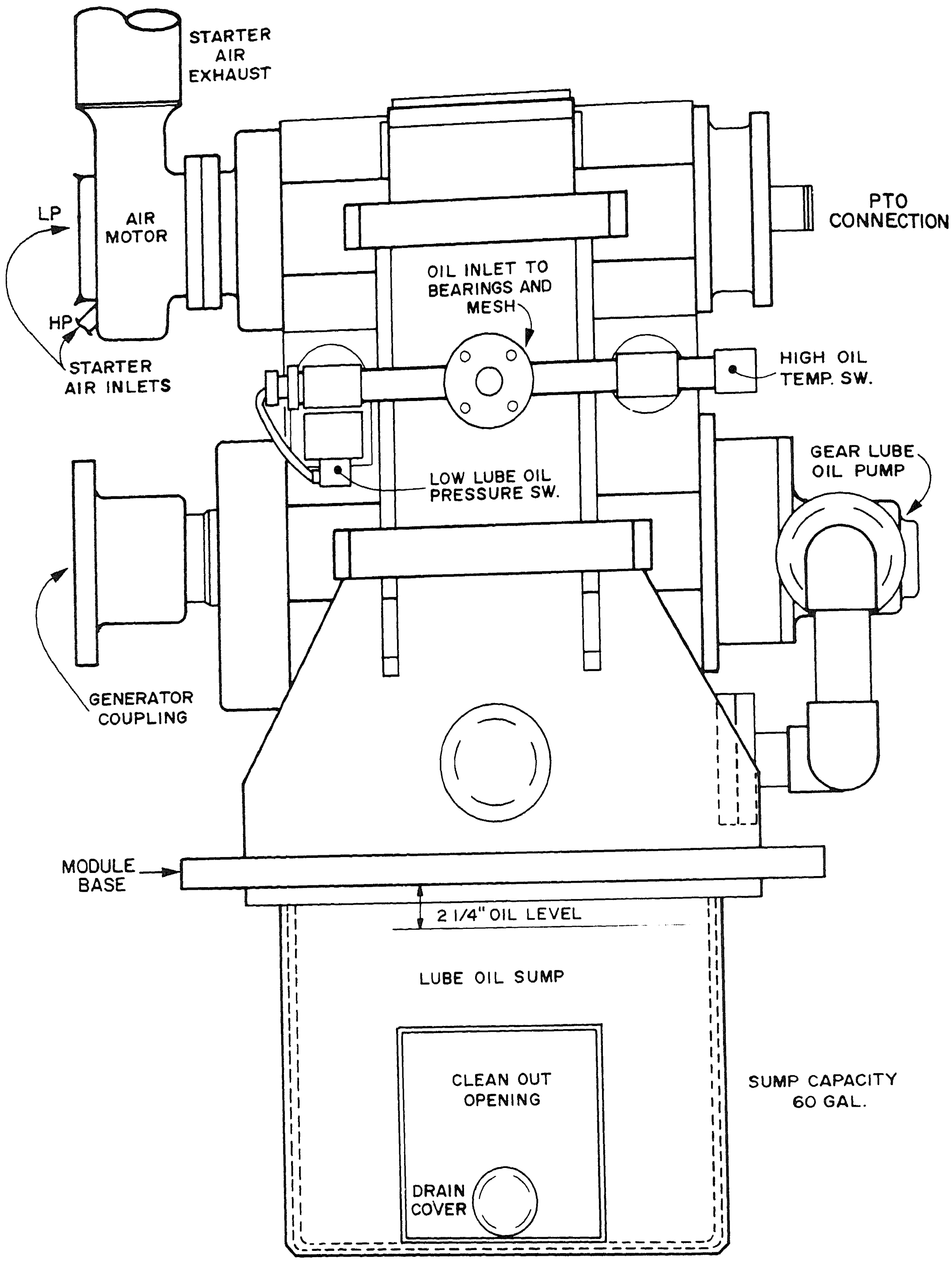

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Figure 8-20.—GTGS reduction gear assembly.

transmits the torque produced by the engine to the reduction gear. It also provides the means to measure the engine speed with a magnetic pickup over the exciter wheel teeth.

Power Take-off Shaft and Adapter

The PTO shaft is a solid steel shaft. It is bolted to the shaft adapter at the forward end and splined to the compressor extension shaft at the aft end. Forty equally spaced teeth are machined on the flange at the forward end of the shaft. These provide excitation for the speed sensor.

Housing

The housing encloses the shaft, supports the forward end of the engine, and contains the midbearing assembly. The housing also provides the mounting for the speed sensor assembly. The midbearing assembly prevents the shaft from whipping.

GTGS REDUCTION GEAR AND STARTER

The reduction gears used to couple the engine to the generator on the two models of GTGSs are identical.

The reduction gear (figure 8-20) is a single reduction, single helical gear type of speed reducer. The reduction ratio is 7.678 to 1. The gear is an over-under, vertically offset, parallel shaft design. It uses a three-piece housing split horizontally at the center lines of the high-speed shaft and the low-speed shaft. The gear elements are supported in sleeve bearings. The starter is mounted on the gear case and drives the high-speed shaft. The oil pump is located at the blind side of the low-speed shaft. The reduction gear is coupled to the generator by a diaphragm-type flexible coupling.

LUBE OIL SYSTEM

The reduction gear lube oil system (figure 8-16) is a wet sump, force-feed system. The sump has a capacity of 60 gallons. It is an integral part of the reduction gear assembly. It also serves as the supply tank for the GT lube oil system. Oil from the sump is picked up by the reduction gear supply pump rated at 40 gpm at 1800 rpm. From the pump, the oil passes through a 25-micron base-mounted filter and through a remotely mounted oil cooler. It is then distributed to the reduction gear, PTO assembly, and to the engine. Pressure at this point is regulated at 25 psig. Oil to the engine and PTO assembly is regulated to 15 psig.

Oil to the PTO assembly is directed by a nozzle onto the shaft coupling. It is then returned by gravity to the sump. The shaft midbearing is lubricated by a spray nozzle on the front of the compressor extension shaft housing. Oil to the reduction gear assembly, 30 gpm at 25 psig, lubricates the reduction gears and bearings. It returns by gravity to the sump.

AIR START SYSTEM

The engine air start system (figure 8-21) has an air turbine starter, a starter exhaust system, and two independent air supply systems. Each system has its own control valve. Air from the LP starter air control valve enters the starter inlet scroll through a 3-inch line. Air from the HP starter air control valve enters the inlet scroll through a 1 1/2-inch line. Exhaust air from the starter is discharged through a 6-inch line into the engine module cooling air duct downstream of the fire damper.

Low-Pressure Air Start System

Air from the ship's bleed air system enters the starter LP air control valve. The control valve is a normally closed, solenoid-operated regulating valve. It regulates airflow to the starter at 1.83 lb/sec at 45 psig.

High-Pressure Air Start System

Air from the HP air flasks enters the starter HP control valve. The control valve is a normally closed, solenoid-operated regulating valve. It regulates airflow to the starter at 2.75 lb/sec at 450 ± 50 psig. A bypass line with an orifice and a pilot valve provides for smooth engagement of the starter teeth. An HP start signal will cause the pilot valve to open. This allows air to flow through the orifice to the starter at less than 50 psig to engage the starter teeth. After about

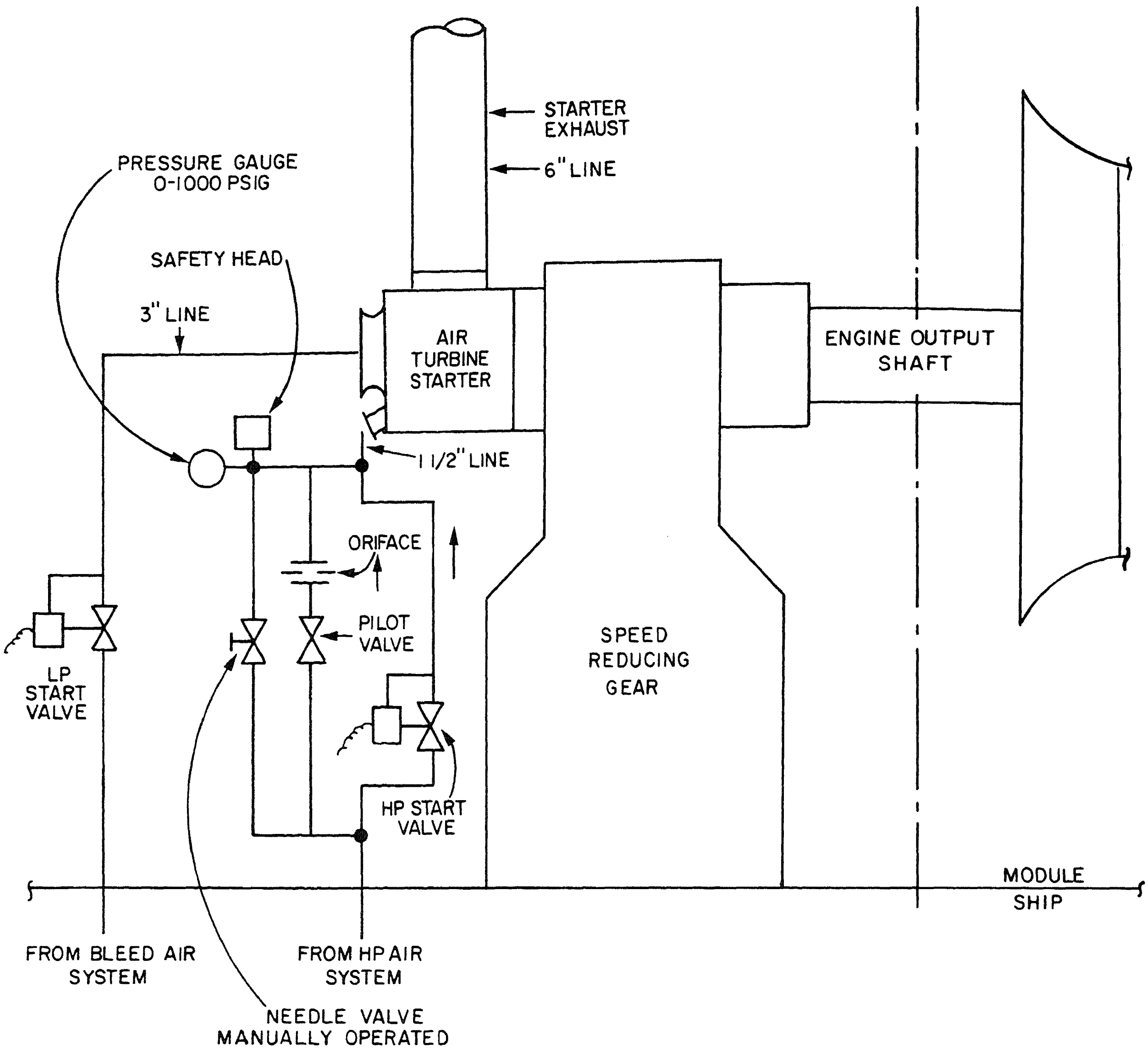

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Figure 8-21.—GTGS air start system.

one-quarter second, the pilot valve will cause the air control valve to open. Full pressure (about 500 psig) is then applied to the starter for rotation. A manual needle bypass valve is provided for manual HP starting.

Air Starter Motor

The Bendix air turbine starter is mounted on the generator side of the reduction gear high speed input shaft. It drives the engine through the reduction gear during the start cycle.

ALTERNATING CURRENT GENERATOR AND VOLTAGE REGULATOR

Two different a.c. generators are powered by the Allison 501-K17 engine. The Model 104 GTGS is a 2000-kW, 3200-amp unit whereas the Model 139 GTGS is a 2500-kW, 4000-amp unit. Both generators output 450-volt, 60-Hz, 3-phase a.c. at a 0.8 power factor with an 1800 rpm input. Both units are totally enclosed, salient pole, two

bearing construction. Each unit has an air cooler mounted above it to cool the generator. An independent lube oil system using 2190 TEP lube oil provides lubrication for the generator bearings.

MODEL 104 GENERATOR

The Model 104 generator has eight major components. The following eight items are keyed to the components shown in figure 8-22.

1. Stator assembly of four-pole, four-circuit, delta connection
2. Rotor assembly with four salient poles
3. Front and rear end bracket assemblies
4. Front and rear bearing assemblies
5. Rotor slip ring brush assembly
6. Overhung permanent magnet alternator and lube oil pump assembly
7. Air cooler assembly
8. Stator terminal/connection box

The field rectifier assembly of the exciter/voltage regulator is also mounted in the airstream within the generator enclosure.

The generator may be overloaded for a short time as follows:

2120 kW 0.8 PF (2650 kVA)
3400 amperes 30 minutes

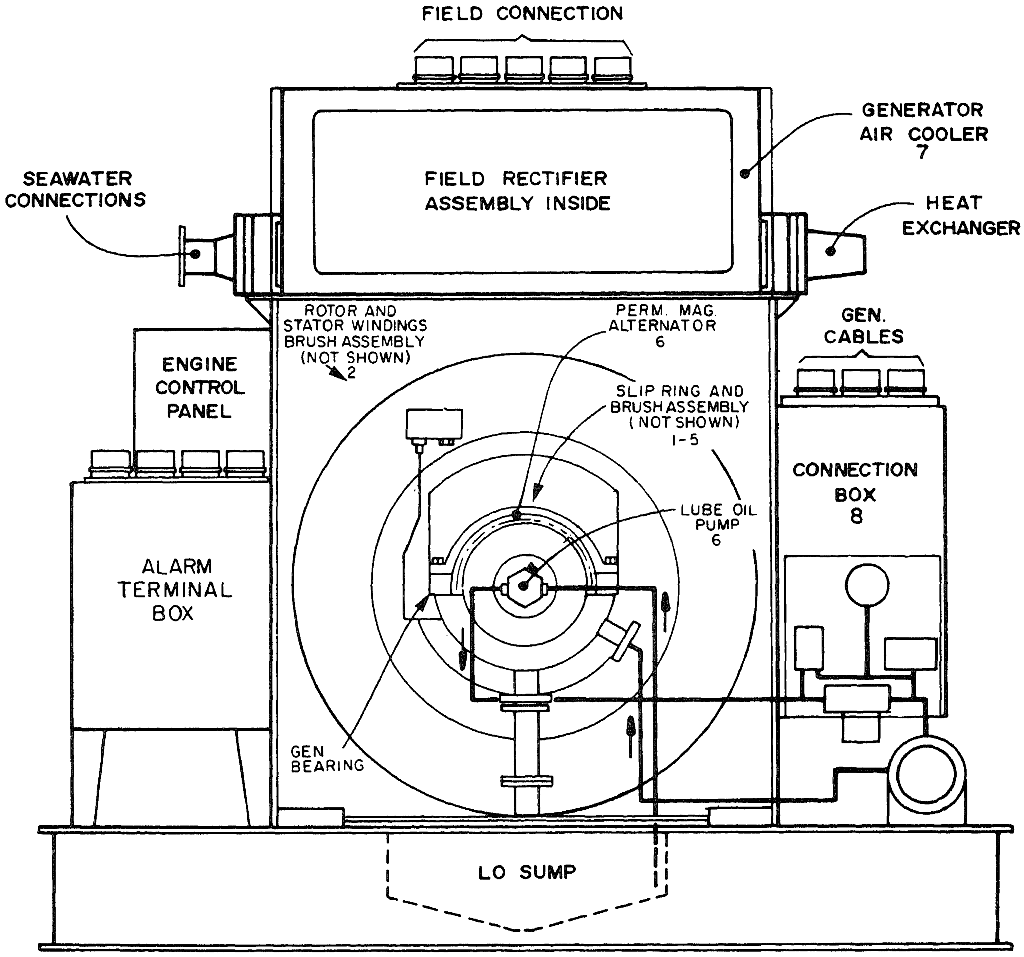

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Figure 8-22.—Model 104 generator.

1875 kW 0.5 PF (3750 kVA)
4810 amperes 2 minutes

MODEL 139 GENERATOR

The Model 139 generator has eight major components. The following eight items are keyed to the components shown in figure 8-23.

1. Stator assembly of four-pole, four-circuit, delta connection
2. Rotor assembly with four salient poles
3. Front and rear end bracket assemblies
4. Front and rear bearing assemblies
5. Brushless exciter assembly
6. Permanent magnet alternator and lube oil pump assembly
7. Air cooler assembly
8. Stator terminal/connection box

The brushless exciter assembly of the generator is connected to the airstream within the generator enclosure by ductwork.

The generator may be overloaded for a short time as follows:

2750 kW 0.8 PF (3437 kVA)
4410 amperes 30 minutes

2344 kW 0.5 PF (4688 kVA)
6014 amperes 2 minutes

AIR COOLER

The housing air cooler assembly is mounted in the generator above the generator frame. It is

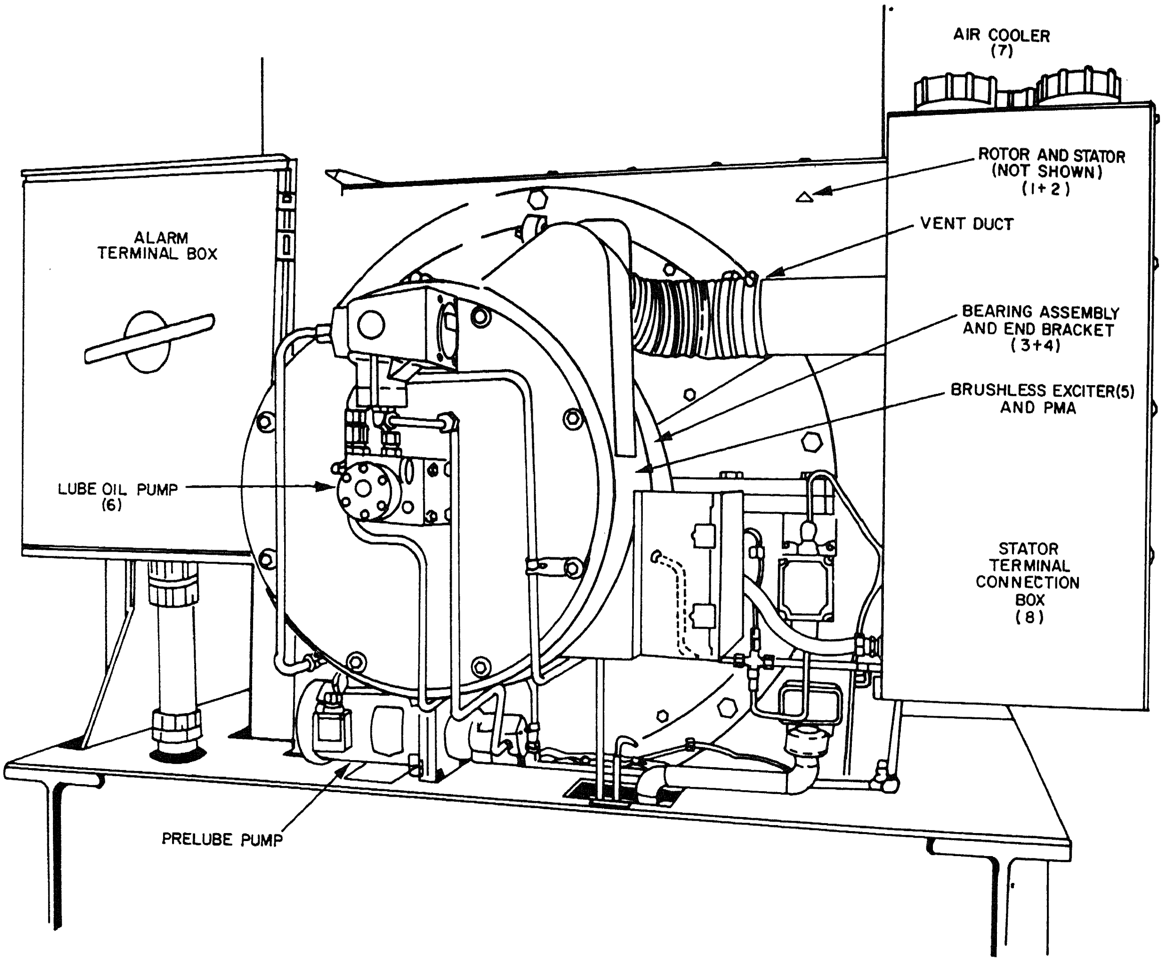

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Figure 8-23.—Model 139 generator.

an air-to-water, double-tube, extended fin-type heat exchanger. It has a core assembly and two water boxes with four zinc anode pencils. The pencils are replaceable units. They are inspected periodically using maintenance procedures. Flanged connections on one water box provide for seawater inlet and outlets. The tubes of the core have a plain inner tube and an internally fluted outer tube. The outer tube carries the aluminum cooling fins. In a leaking inner tube, the outer tube provides a water passage to the leakage compartment at each end of the core. Each leakage compartment has a telltale space vent and a telltale drain.

LUBE OIL SYSTEM

The generator lube oil system (figure 8-24) is independent of the gas turbine/reduction gear

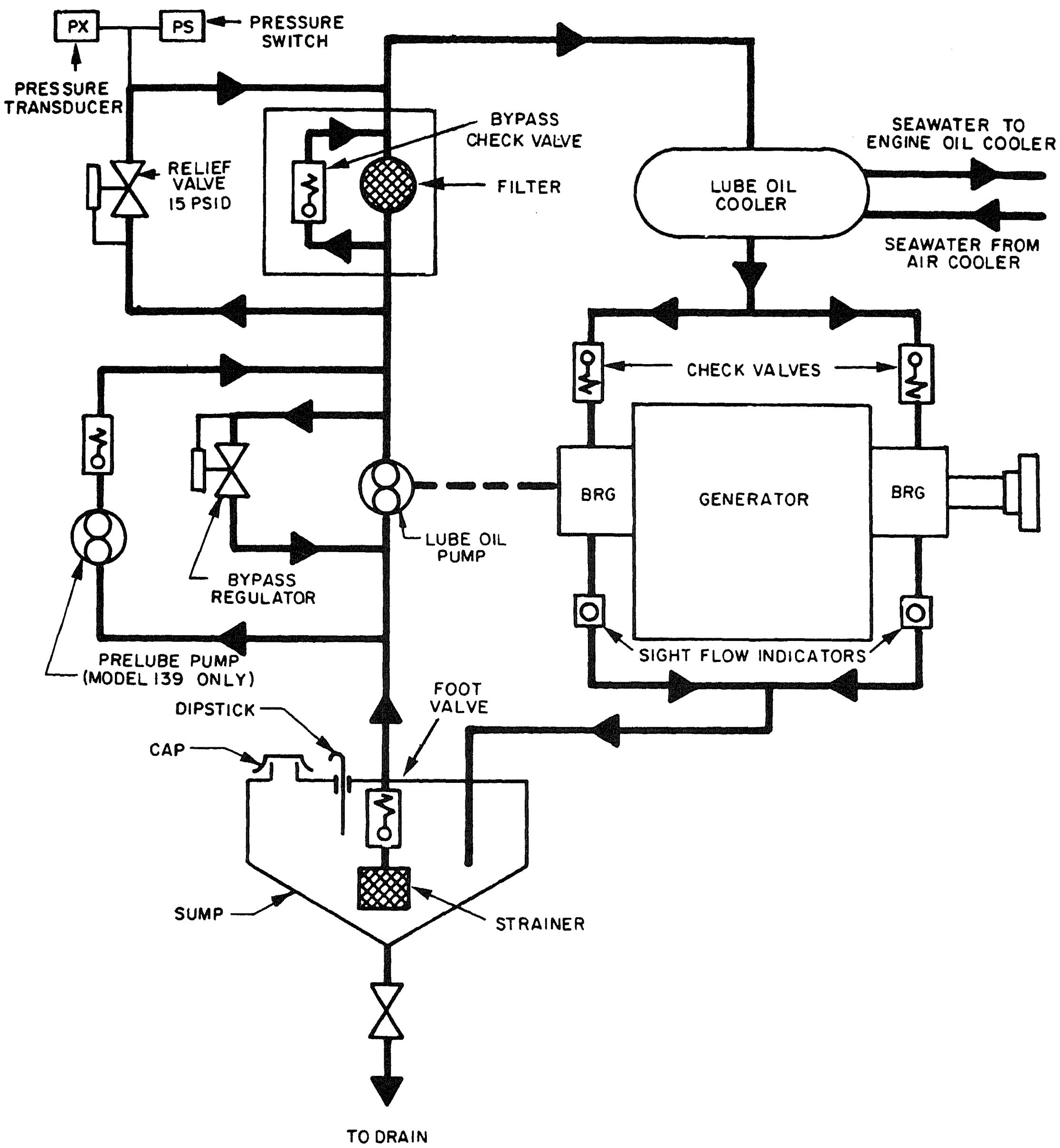

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Figure 8-24.—Generator lube oil system.

lube oil system. The generator system uses mineral oil (2190 TEP). It force-feeds the two bearings with 3 gpm at 12 to 15 psig pressure. Oil is taken from the sump tank in the GTGS base by a pump mounted on the permanent magnet alternator shaft. The oil is then passed through a 25-micron filter and the base-mounted cooler before reaching the sleeve bearings. Gravity flow through a sight glass returns the oil to the sump. On the Model 139 a prelube pump is installed to provide the initial lubrication to the generator upon start-up.

SPACE HEATERS

Electric heater elements are mounted at the bottom of the generator. They prevent the condensation of moisture when the generator is secured or on standby. Four 120-volt, 250-watt, tubular, finned heaters are mounted crosswise under the stator. They are spaced to distribute heat along the length of the stator. A heater control switch with an indicator lamp is mounted on the control section of the switchboard. An interlock on the generator circuit breaker automatically disconnects the space heaters when the breaker is closed.

TEMPERATURE MONITORING

Nine copper RTDs are embedded in the generator stator winding slots. The three-wire lead of each RTD is brought to an internal terminal board. A rotary selector switch and a temperature indicator are mounted on the LOCOP for monitoring six stator winding temperatures. The three remaining RTDs serve as spares.

A tip-sensitive RTD is embedded in the babbitt of each generator bearing. A terminal assembly, connector, and straight plug are provided for each RTD. A rotary selector switch and temperature indicator, mounted on the LOCOP, selects and monitors the two bearing temperatures. Both stator and generator bearing RTD outputs are signal conditioned at the LOCOP. They are transmitted to the engineering control and surveillance system (ECSS) for monitoring.

VOLTAGE REGULATION

The two GTGSs use different voltage regulators. The major components of the voltage regulators are mounted in the generator or in the generator control unit (GCU). The GCU is mounted in the same area as the switchboard.

Model 104 Voltage Regulation

The following four items are the major components of the Model 104 voltage regulator (figure 8-25).

1. Static exciter/voltage regulator assembly deck mounted near the associated switchboard
2. Field rectifier assembly mounted in the generator enclosure air path
3. Motor-driven rheostat mounted on the associated switchboard for manual voltage control
4. Mode select rotary switch mounted on the associated switchboard

The GCU provides generator field excitation at about 100 amperes at 150 volts d.c. at full load. Voltage control is in automatic or manual modes. Figure 8-25 is the GCU functional diagram.

GENERATOR FIELD EXCITATION.—Excitation power for the generator field is supplied by the generator output. It is controlled by a three-phase magnetic amplifier. Different values of d.c. flowing in a control winding provide different levels of saturation in the magnetic amplifier. This controls the output of the magnetic amplifier to the generator field.

Another source of field excitation comes from three current transformers (CTs). This is rectified by a three-phase, full-wave bridge in the field rectifier assembly. Since the source of field excitation for the magnetic amplifier comes from the generator output, a short circuit on the system will cause the voltage to collapse. This results in a loss of excitation voltage. The excitation source from the CTs can supply enough excitation to the generator field under short circuit conditions to keep the generator output at a minimum 320 percent of rated current. In this way the overcurrent devices can sense the short circuit. They can trip the generator breaker to clear the fault.

On initial start-up of the generator, the magnetic amplifier has little or no excitation voltage. To assure that the generator voltage will build up, another source of excitation must be used. Excitation is supplied by the permanent-magnet alternator (PMA) on the generator shaft extension. It is rectified through a three-phase, full-wave bridge. The output voltage of this excitation source is less than the normal output of

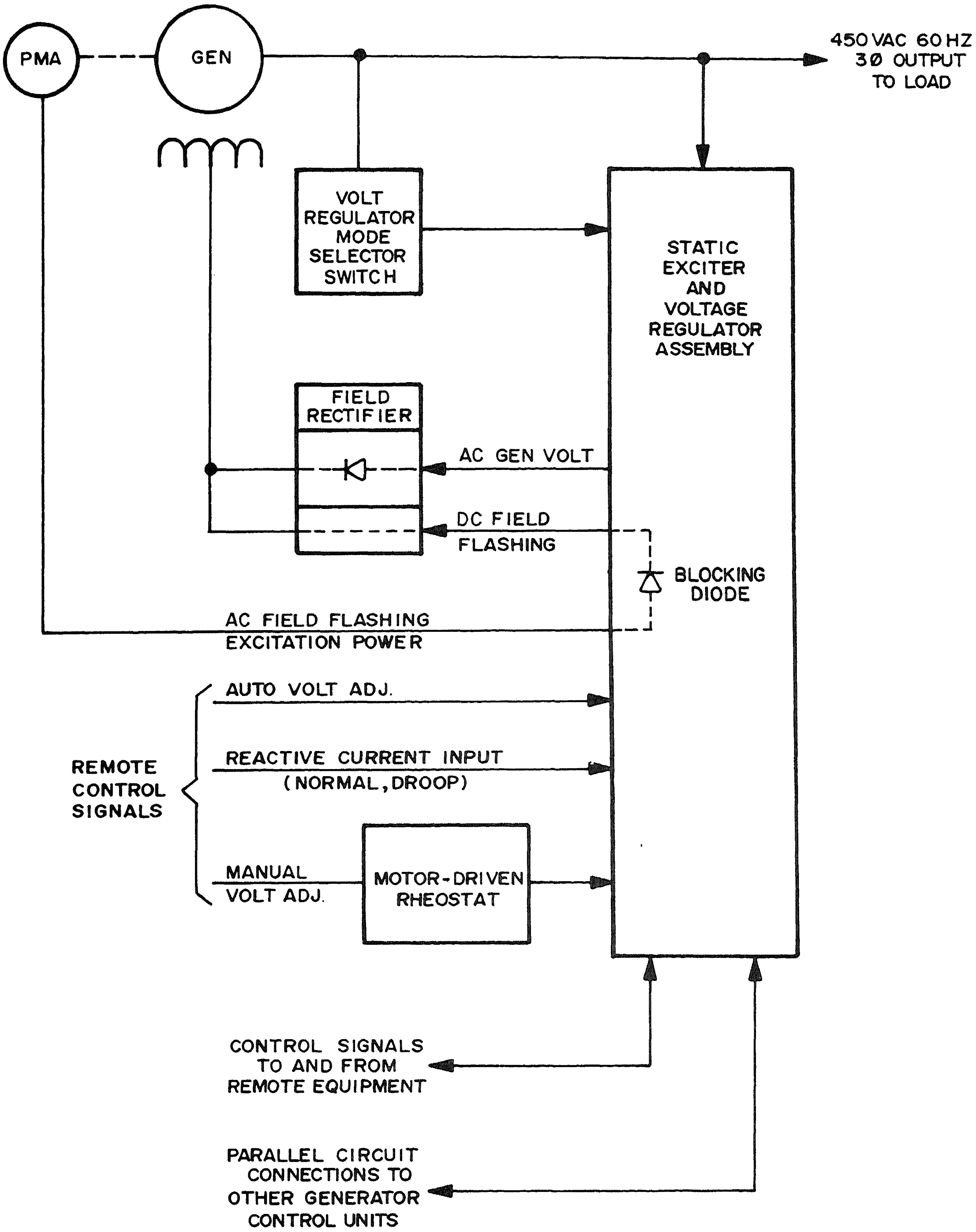

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Figure 8-25.—Model 104 voltage regulator functional diagram.

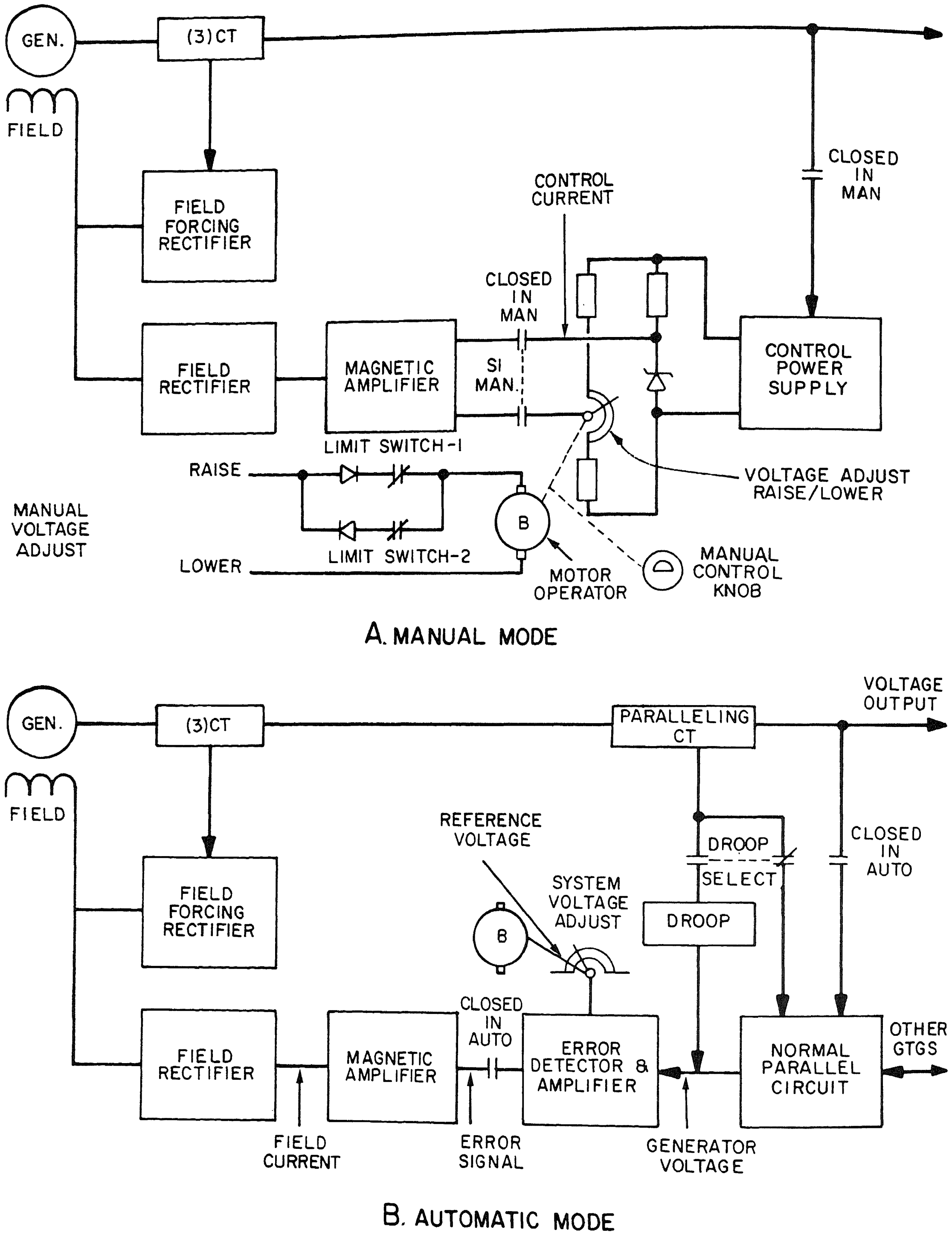

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Figure 8-26.—Model 104 manual and automatic voltage regulation.

the magnetic amplifier at 450-volt generator output. Therefore, it is automatically removed by a blocking diode once the magnetic amplifier output takes over. This function is called field flashing.

Under manual operation (figure 8-26, item A), the source of control current for the magnetic amplifier is an internal power supply. You can adjust the control current from the switchboard by the MANUAL MODE VOLT ADJ knob or the GEN VOLTAGE RAISE-LOWER switch (with the VOLT REG MODE switch in the MAN position). With the EPCC in manual control, the control current may also be varied through the VOLT LOWER-OFF-RAISE switch at the EPCC.

In automatic operation (figure 8-26, item B), the voltage regulator output supplies control current to the magnetic amplifier fields. An internal motor-driven rheostat sets the required voltage. Control for this motor is from the switchboard for local operation and from the EPCC for remote operation.

VOLTAGE REGULATOR.—The voltage regulator in auto operation compares generator voltage with a reference voltage to provide an error signal (figure 8-26, item B). This error signal is amplified and applied to the magnetic amplifier control winding. This changes the output of the magnetic amplifier. This, in turn, provides field current to set the output voltage of the generator. The reference voltage is adjustable through the motor-driven rheostat in the static exciter/voltage regulator assembly.

A line current signal is brought in from the three paralleling CTs to the field forcing rectifier. This provides two functions in automatic mode.

1. When an individual generator is on line, this current signal acts to compensate for load changes. When load increases, this signal will call for an increase in excitation. This relieves the voltage regulator of having to make the entire correction with its error signal. This load compensation increases the accuracy of voltage regulation.
2. When two generators are operating in parallel, their voltages are equal. Therefore, any adjustments in the excitation of individual machines can only change the power factor of both machines. This creates circulating reactive currents between machines. In this case, the current signal brought in from the paralleling CT will help regulate the division of reactive line current. This reduces circulating current between machines.

Model 139 Voltage Regulation

The major components of the Model 139 voltage regulator (figure 8-27) consist of the following:

1. Two voltage regulator assemblies (normal and standby), mounted in the GCU enclosure
2. Motor-operated rheostat for auto voltage regulation, mounted in the GCU enclosure
3. Brushless exciter assembly, mounted on the generator
4. Permanent magnet alternator (PMA), mounted on the generator
5. Auto Voltage Control RAISE-LOWER switch, mounted in associated switchboard
6. Motor-operated variac for manual voltage adjustment, mounted in the associated switchboard
7. Mode select

The GCU provides brushless exciter field excitation and voltage control in the automatic control modes.

GENERATOR FIELD EXCITATION.—Main generator field excitation is supplied by a brushless exciter assembly. The brushless exciter assembly has three main parts: stator, rotor, and rectifier assembly. The rotor and rectifier assembly are attached to the generator shaft. They turn inside the stator that is attached to the generator frame. The operation of the exciter is similar to that of any a.c. generator. The exception is the rotor and stator functions have been reversed. When d.c. is passed through the exciter field winding, lines of flux are created that pass through the air gap. This creates a three-phase a.c. output from the rotor. This three-phase a.c. is rectified to d.c. by the rectifier assembly. It is then conducted through the generator field. An advantage of using this brushless exciter over the brush slip ring type of generator is the greatly reduced maintenance.

VOLTAGE REGULATOR.—Two solid-state voltage regulators (normal and standby) control the exciter field in normal automatic operation (figure 8-28). Indicator lights on the face of the

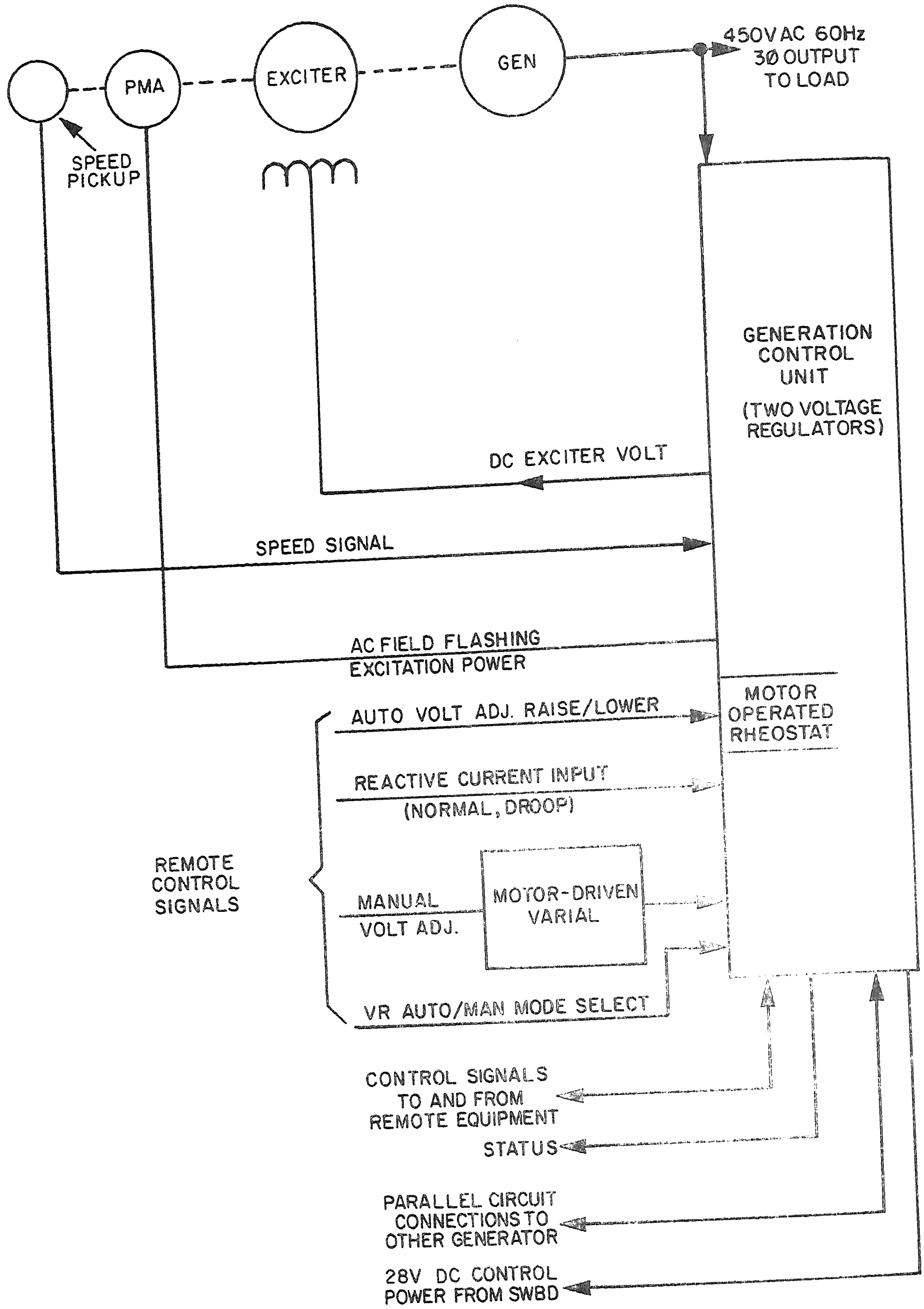

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Figure 8-27.—Model 139 voltage regulator functional diagram.

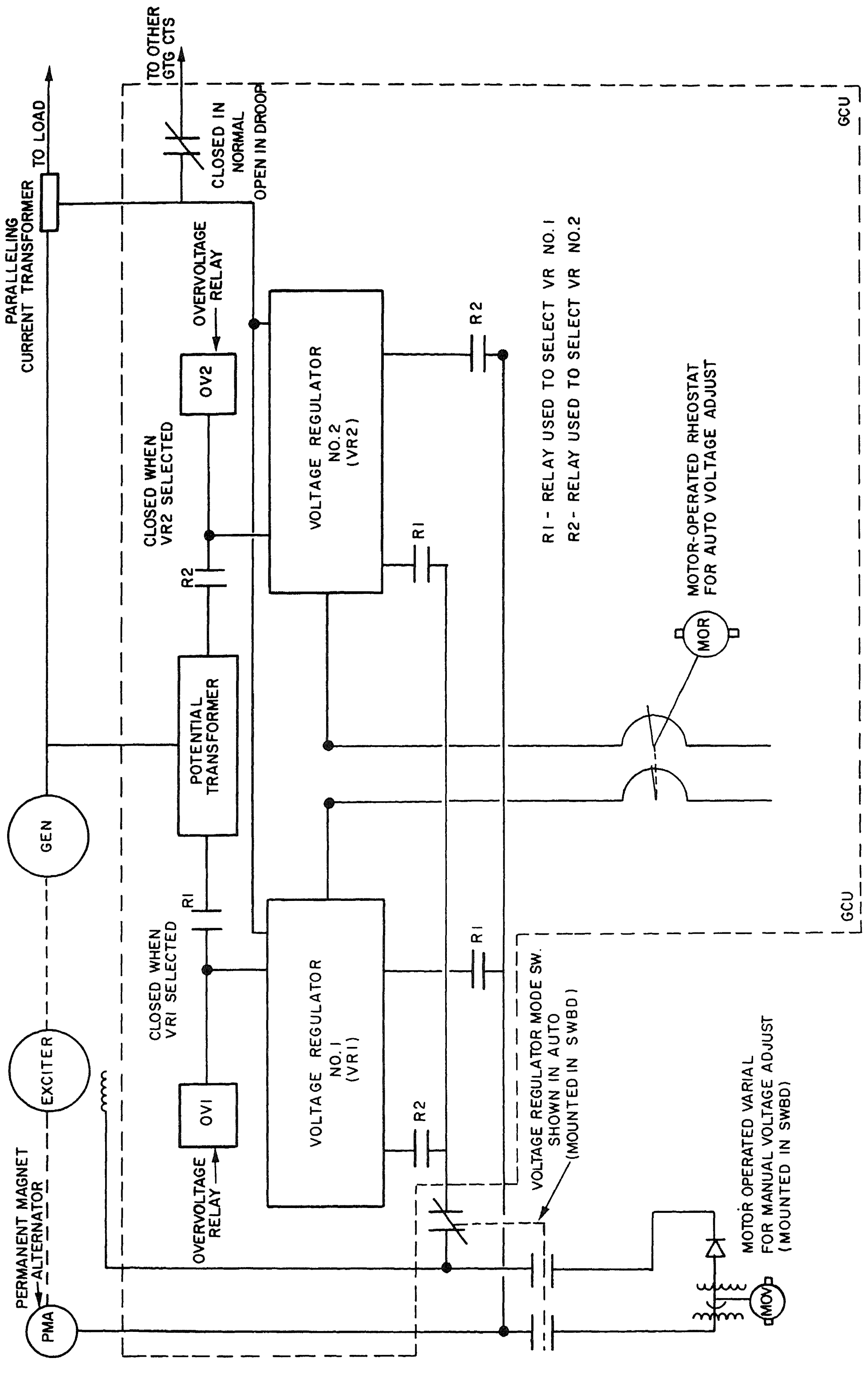

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Figure 8-28.—Model 139 voltage regulator.

GCU depict which regulator is in use. Overvoltage relays are provided to automatically switch regulators if a regulator fails. This prevents an overvoltage condition. An indicating light on the face of the GCU will illuminate when a regulator fails. A RESET pushbutton is provided on the face of the GCU. When depressed, it will return control to the (normal) regulator. It also extinguishes the regulator failed light. Manual or automatic control may be selected at the switchboard by the VOLT REG MODE-OFF/AUTO/MANUAL control. The regulators receive their power from the generator output through potential transformers. Thus, on initial start-up of the generator in automatic mode, the voltage regulator will have little or no excitation voltage. To assure that the generator voltage will build up, excitation is obtained from the PMA. A relay internal to the regulator will divert power from the PMA to the generator field until voltage has risen about 350 volts (75 percent of rated). Then, the relay will switch excitation control over to the regulator.

The source of regulator power is the generator output. Therefore, a short circuit on the system will cause the voltage to collapse. This results in a loss of excitation voltage. If a short circuit occurs, a relay internal to the regulator will transfer excitation from the regulator to the PMA. This is done if the voltage drops below about 225 volts. This will allow the generator to supply enough current to activate overcurrent devices. It will also trip the generator breaker to clear the fault.

In manual operation, the generator excitation is controlled by the motor-operated variac mounted in the switchboard. Power is received from the PMA. It is scaled by the variac, then rectified and conducted to the exciter field (figure 8-29). You can make adjustments at the switchboard by turning the Manual Mode Volt Adjuster knob (with the VOLT REG MODE switch in the MAN position). When in the manual mode, you may make voltage adjustments from the EPCC. Operation of the Voltage Raise/Lower control on the EPCC activates the motor-operated variac. In the manual mode, generator voltage will decrease with load unless field excitation is increased. Thus when operating in the manual mode, observe generator operation carefully.

In automatic operation (figure 8-28), the voltage regulator output supplies control current

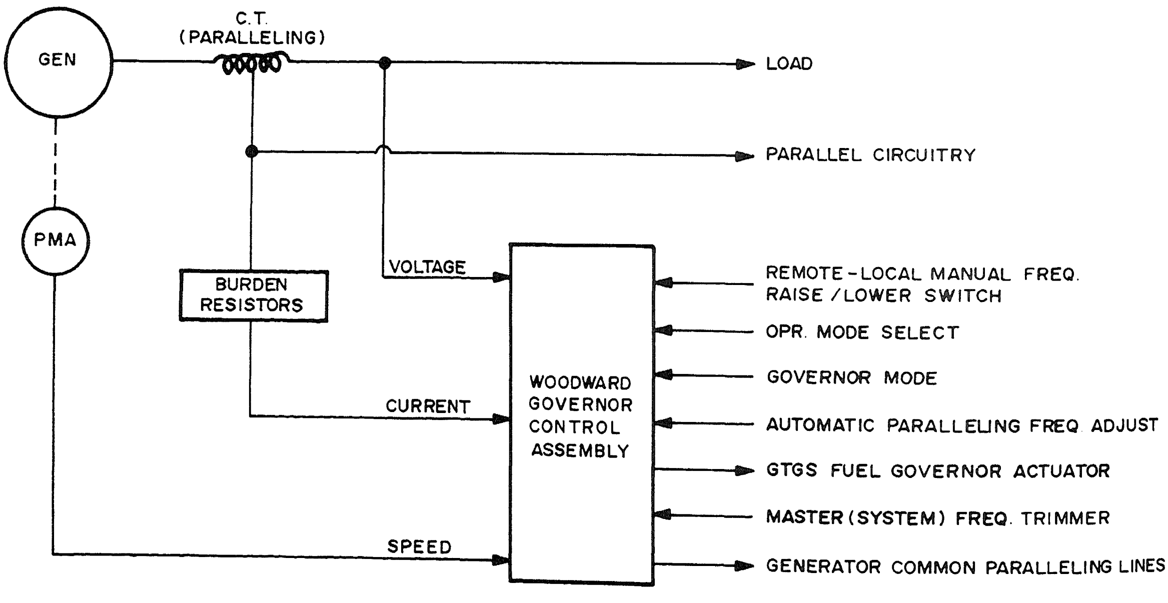

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Figure 8-29.—Woodward 2301 governor interface diagram.

to the exciter fields. The GCU internal motor-driven rheostat sets the required voltage. Control of this motor is from the switchboard Voltage Raise/Lower control for local operation and the EPCC for remote operation. When in automatic, the MASTER VOLTAGE ADJ located on the EPCC will also operate the motor-operated rheostat in the GCU. It changes the reference for the voltage regulator. This command will be parallel to the GCUs. It will raise or lower the reference to all regulators.

A line current signal is brought in from the paralleling CT. It provides two functions in automatic mode.

1. When two generators are operating in parallel, their voltages are equal. Therefore, any adjustments in the excitation of individual machines can only change the power factor of both machines. This creates circulating reactive currents between machines. In this case, the current signal brought in from the paralleling CT will help regulate the division of reactive line current. This reduces circulating current between machines.

2. When two generators are operating in parallel and in droop mode, the reactive current signal will produce a fixed droop in the voltage output of a generator. If an individual generator takes on an increased share of reactive current, its voltage will droop more. This, in turn, will tend to transfer some of that reactive current to the other machine. If both machines have equal voltage droop, they will tend to share reactive currents at various loads. But it is not self-regulating.

SPEED GOVERNING

The Allison 501-K17 is a constant speed engine. That is to say, it will maintain the proper speed (13,821 engine rpm) to output a steady 60 Hz. Dependable 60-Hz power is required to keep electronics and motors operating at their peak output. The Allison 501-K17 uses an electrohydraulic governor to maintain this constant speed. Two different electronic control systems are used on the two models of GTGSs. The Model 104 GTGS uses the Woodward 2301 control system, whereas the Model 139 GTGS uses the Woodward 9900-320 control system. Both Model GTGSs use the Woodward EGB-2P electro-hydraulic actuator.

Both systems normally operate on the EG. The EG will maintain the frequency set by the operator. Once the frequency is set and the load is balanced between GTGSs in parallel, the governor system will maintain the set frequency and load balance. If failure of the EG control occurs, a mechanical flyweight governor will regulate the engine speed. The mechanical governor is set slightly higher than the EG. It will maintain a frequency of about 62 Hz. This mechanical governor prevents overspeed of the engine during an EG failure. It is set by a screw adjustment on the actuator.

2301 GOVERNOR SYSTEM (MODEL 104)

The engine speed governor on the Model 104 GTGS is the Woodward 2301 electrohydraulic control system. It has a backup centrifugal governor override. Two major components within the system are an electronic control unit and an electrohydraulic actuator. The control unit is mounted in the GCU. The actuator is mounted on the GTG. The control unit is a solid-state electronic package. It processes input commands and feedback signals to generate a signal to position the actuator. The actuator positions its output shaft in response to the control signal. This shaft controls the engine's LFV through a mechanical linkage. If the engine speed increases to a preset limit because of a failure in the electronic control, then the centrifugal governor section of the actuator will automatically assume control of the output shaft. Engine speed will then be controlled at a point slightly above the normal operating speed.

The governor system has two basic operating modes, NORMAL (isochronous) and DROOP. The isochronous mode provides constant speed operation, regardless of load. When generators are operated in parallel and in the isochronous mode, the governor system maintains a constant speed. It also controls the load division between paralleled generators. The isochronous mode is selected when the EPCC selector or the switchboard selector is in the NORMAL position. The load sharing function is automatically enabled

when a generator operating in the NORMAL mode is paralleled with another generator.

In the droop mode, the governor system regulates engine speed. The speed will decrease slightly, however, with an increase in load. Sometimes the generator is paralleled with a constant frequency bus (such as shore power) while in the droop mode. In this case, the governor cannot control speed since it is held constant by the bus frequency. Instead, it will control the load carried by the generator. In this way, the droop mode provides load control of a generator paralleled with shore power. It also can unload a generator paralleled with another GTGS without disturbing system frequency. When the selector is in the DROOP position, droop mode is selected at the EPCC or the switchboard.

The operating point of the governor is set by a motor-operated potentiometer. It is located at the electronic control unit. The individual frequency adjust controls at the EPCC or the switchboard are used to adjust the potentiometer. These controls adjust the position of the motor-operated potentiometer to a higher or lower position. If generators are operated in parallel from the EPCC, with the system frequency controls enabled, the motor-operated potentiometer returns to a calibrated 60-Hz position. You can make adjustments by using the SYSTEM FREQUENCY ADJUST control at the EPCC. This control will position a master frequency trimmer in the EPCC. It sends equal adjust signals directly to each generator's electronic control unit. Therefore, the frequency of the bus can be changed without disturbing the load balance between operating units. During automatic paralleling operations, the automatic paralleling device (APD) will adjust the oncoming generator for synchronization. This adjust signal is also a direct input into the electronic control unit. It is in effect only during automatic paralleling conditioning. Figure 8-29 is a governor interface diagram.

Electronic Control Unit

The electronic control unit of the 2301 governor system is modular in design. It has eight major subunits. The following terms are a list of these subunits and are keyed to figure 8-30, a functional diagram of the 2301 governor.

1. Summing amplifier
2. Load sensor
3. Frequency sensor
4. Two power supplies
5. Motor-operated potentiometer
6. Accessory box
7. Two filters

The motor-operated potentiometer (1) supplies a reference to the amplifier. When the electric plant operates in manual, manual permissive, or droop mode, frequency adjust commands will cause the motor to rotate in the raise or lower direction. This changes the reference correspondingly. When operating in the automatic mode, the motor automatically drives to and remains at 60 Hz. This position is established by the motor's limit switches. External adjustments to the governor system are done by additional inputs to the amplifier. These inputs come from either the master frequency trimmer (2) or the APD (3).

The amplifier (4) provides the current to the actuator (5). This current is varied in response to the inputs to the amplifier. This includes the reference, frequency feedback, and load sensing. Input changes because of load, speed, or reference cause the amplifier current to reposition the actuator output shaft. This increases or decreases fuel flow. Amplifier current then stablizes at a new setting that satisfies all inputs. The amplifier is reverse acting. That is, the larger the input (error signal), the smaller the output current to the actuator. The actuator output shaft is designed to work so a decrease in current causes it to drive the LFV toward the maximum fuel position. If the amplifier fails and the current goes to zero, the actuator will be positioned in the maximum fuel position. (The centrifugal governor assumes control if engine speed increases to the preset limit.)

The PMA input to the control unit provides voltage for the two power supplies (6) and a frequency feedback signal to the frequency sensor (7). One power supply feeds the amplifier; the second provides power for the motor-operated potentiometer. The frequency sensor converts the PMA output (8) (about 120 volts a.c. at 420 Hz)

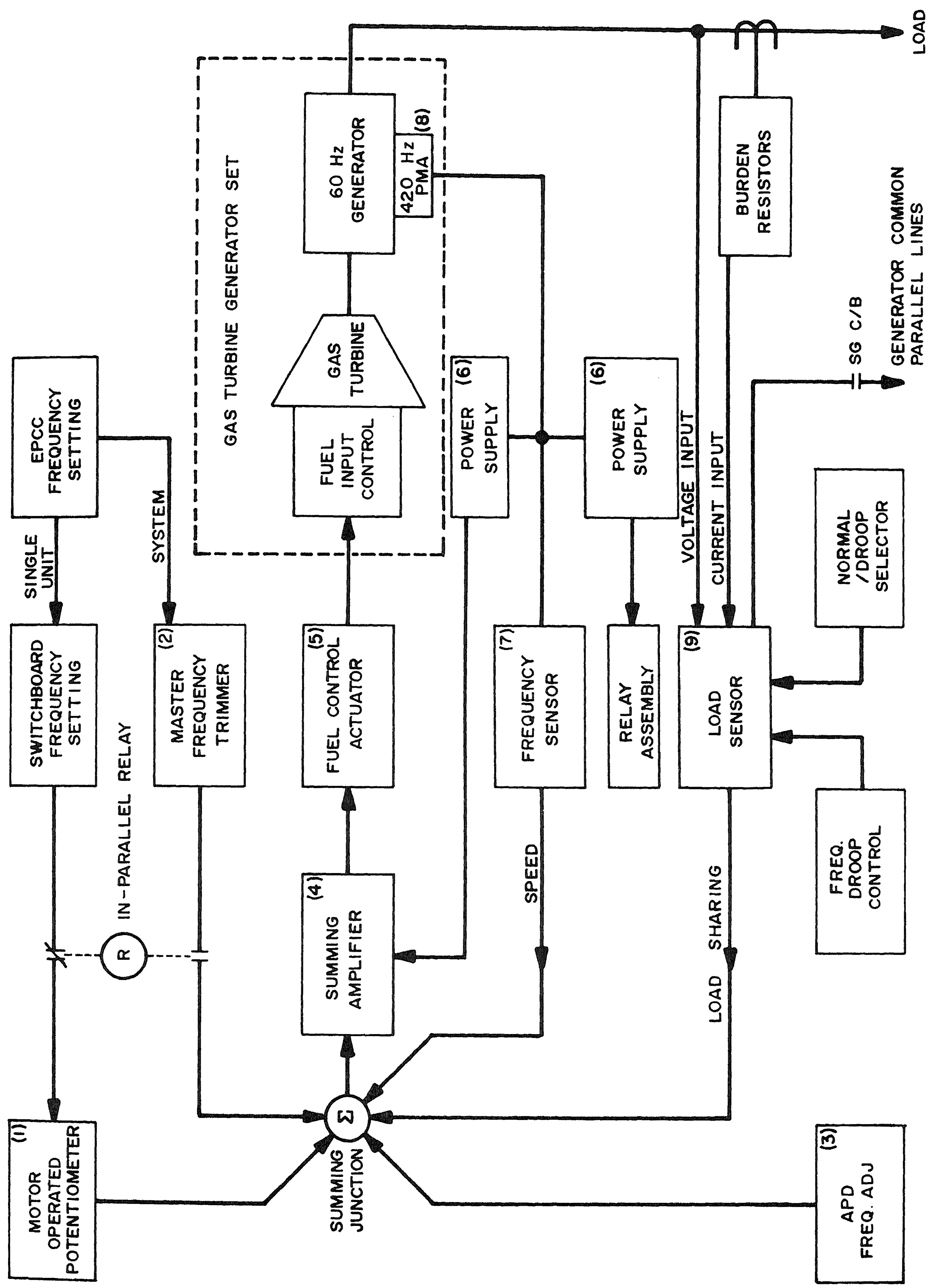

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Figure 8-30.—2301 governor functional diagram.

to a proportional d.c. voltage. This is used for the frequency feedback input to the amplifier.

The load sensor module (9) controls load sharing in parallel isochronous operation. It is used to generate the droop characteristics during droop operation. Power generated by the generator is measured by transformers. They supply voltage to a bridge circuit. For load sharing, the bridges of each paralleled generator are connected so an unbalance because of uneven loads causes an input to each governor amplifier. This forces proportional fuel adjustments until the loads are balanced between the two units. This also balances the bridge circuits. The amplifier input is again returned to algebraic zero volts d.c. Sudden shifts in load demand cause pulses to be developed in the load sensor. This upsets the algebraic zero voltage of the governor amplifier. This results in quicker response to load changes. Polarity of the pulse is also sensed to determine the direction of load changes.

During droop mode some of the load sensor output opposes the action of the amplifier speed reference. The input to the amplifier will be decreased by an amount proportional to load, resulting in droop.

If the generator is not paralleled with another source, this droop will result in a decrease in frequency. The decrease is proportional to the increase in load. If the generator is paralleled with an infinite bus (such as shore power), droop provides load control. When paralleled with an infinite bus, the speed of the machine is held constant by the bus. The governor system, therefore, cannot control speed. Any attempt to increase or decrease speed will only result in an increase or decrease in load. Without the droop characteristics, the governor system would attempt to adjust the frequency to satisfy the reference exactly. Thus, it will cause the load to increase beyond generator capacity or decrease until the flow of power reverses. The droop input, however, will modify the speed reference. The governor will reach a stable operating point even though the frequency does not match the reference. This operating point is set by the speed reference and droop input (since frequency is constant). It determines the load on the generator. Under this condition, the load on the generator will remain constant for any reference setting.

Centrifugal Governor

The independent centrifugal governor system is used as a backup control system. It backs up the electronic control unit of the Woodward governor system. The centrifugal governor speeder spring device takes over control if (1) the electronic control unit fails and (2) the engine speed increases due to the actuator positioning itself for full speed failure mode. This is at about 62 Hz (depending on load) or the equivalent speed of about 14,300 rpm. This is 480 rpm above the 60-Hz speed of 13,821 rpm. The centrifugal governor is part of the hydraulic actuator assembly.

Master Frequency Trimmer

A master frequency trimmer in the EPCC provides frequency control to any two or all three generators when operating in parallel. You may use the EPCC panel SYSTEM FREQ RAISE/LOWER switch to demand a change of frequency for the paralleled units. This control inputs 115 volts a.c. into a reversible motorized potentiometer assembly. The potentiometer output is a d.c. signal. Its amplitude is proportional to the correction demanded in the generator output frequency. The polarity dictates the direction of change. This potentiometer assembly is located at the EPCC and is shown on figure 8-30.

9900-320 GOVERNOR SYSTEM (MODEL 139)

The engine speed governor on the Model 139 GTGS is the Woodward 9900-320 electrohydraulic control system. It also uses a backup centrifugal governor override. There are eight components within the system. These components are shown on figure 8-31, an interface diagram of the 9900-320 governor. They are an electronic fuel control, an LFV with an LVDT, an EG-B2P actuator, an Allison speed and temperature module, a CIT sensor, a magnetic pickup, a speed phase matching (SPM) synchronizer, and a master frequency trimmer. Following is a list of these

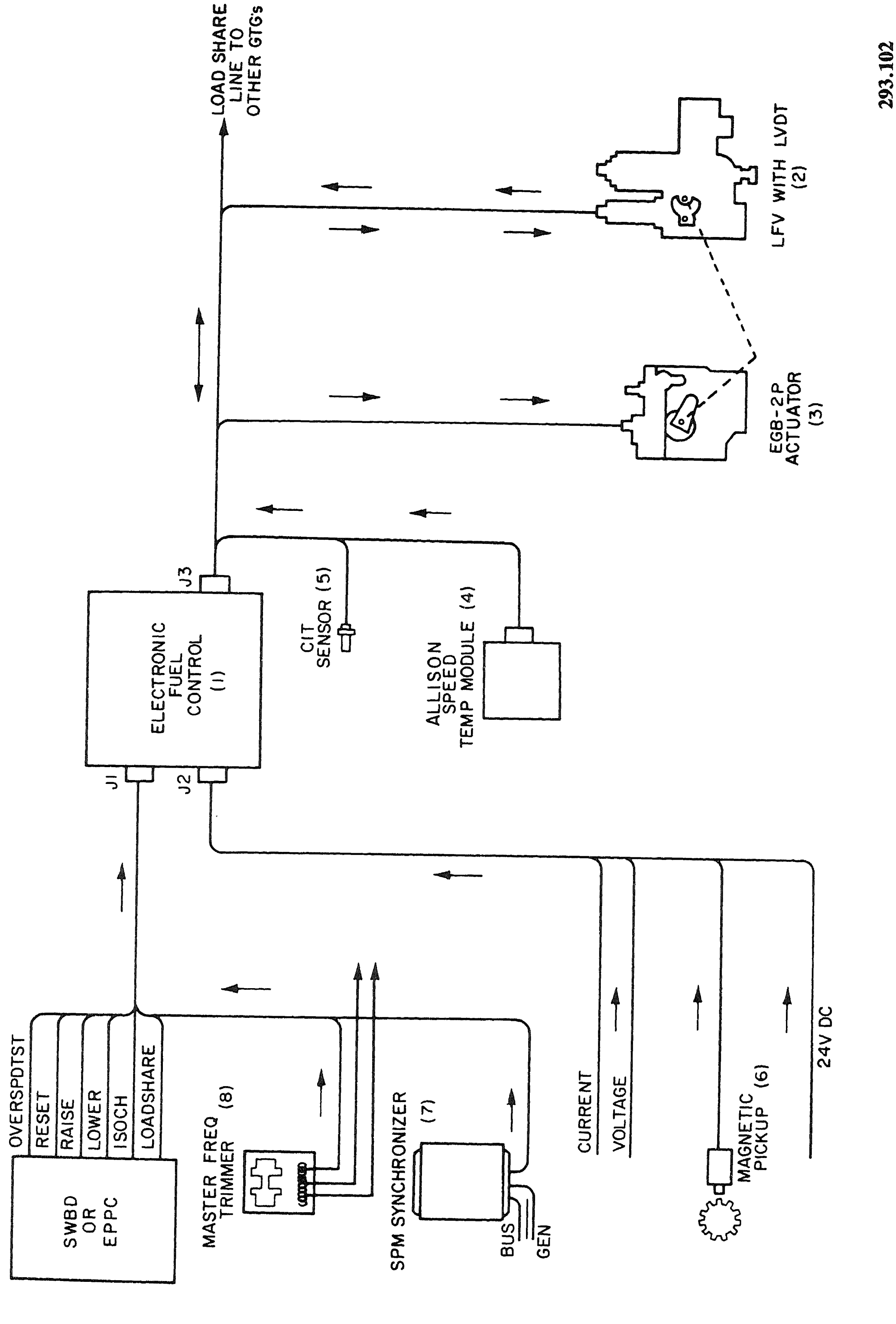

Figure 8-31.—9900-320 governor interface diagram.

eight components and a brief description of their functions. The items are keyed to figure 8-31.

1. The electronic fuel control regulates fuel during turbine lightoff, temperature control, acceleration, and 60-Hz power generation.
2. The LFV with LVDT meters the fuel to the engine.
3. The EG-B2P actuator positions the LFV with LVDT.
4. The Allison speed and temperature module monitors the TIT. It supplies a signal to the electronic fuel control. This is for the start fuel schedule and for maximum temperature control.
5. The CIT sensor monitors the ambient air temperature. It applies the signal to the speed correction and acceleration temperature reference circuits.
6. The magnetic pickup senses turbine speed as an a.c. pulse signal with a frequency proportional to the speed of the turbine.
7. The SPM compares the phase of the generator with that of the bus. If an error is sensed, a signal is applied to the fuel control unit. Then the generator phase angle will be brought in phase with the bus.
8. The master frequency trimmer is used when the turbine is in load sharing. It changes power system frequency without changing the load division between engines.

The control unit is a solid-state electronic package. It has input commands and feedback signals. They generate a signal to position the actuator. The actuator positions its output shaft by responding to the control signal. This shaft controls the engine's LFV with LVDT through a mechanical linkage. The LVDT is mechanically linked to the internal metering sleeve. This sleeve meters fuel flow to the engine. If the engine speed increases to a preset limit because of a failure in the electronic control, the centrifugal governor section of the actuator will automatically control the output shaft. Engine speed will be controlled at a point above the normal operating speed.

Like the 2301 governor system, the 9900-320 governor system has two basic operating modes, NORMAL (isochronous) and DROOP. Refer back to the section on the 2301 governor which describes the operating modes.

Electronic Control Unit

The control unit is modular in design and has nine major modules: a load sensor, isolation, speed reference, speed channel, power supply, fuel limiter, temperature channel, final driver, and motherboard. These modules are found in the governor box in the GCU. Figure 8-32 (a foldout at the end of this chapter) is a functional diagram of the governor control. It shows the three major control functions separated by broken lines. These functions are speed control, temperature control, and fuel limiting.

The following paragraphs describe the operation of the electronic fuel control to the board level. The module titles are descriptive of their major function.

LOAD SENSOR MODULE.—This module uses inputs from the generator voltage and current transformers. Each phase is monitored for current and voltage by potential transformers and CTs. This determines the load. Each CT develops a voltage across a burden resistor, proportional to generator current. The signal representing the load on the three phases is summed in the load sensor.

The current in all three phases is corrected for power factor and summed in the load sensor module. This provides a signal proportional to the load on the bus. A load gain potentiometer is located within the load sensor. It determines the percentage of the load that this generator handles in a load sharing situation with other generators.

The droop potentiometer within the load sensor determines the percentage of speed change. This is used when the turbine generator is operating in droop mode. The effect of droop is a decrease in speed setting for an increase in load. A portion of the load gain voltage is applied to the speed channel as a droop signal.

When the turbine is in isochronous mode, the load pulse amplifier provides a speed error correction signal in advance of the normal speed error signal. This improves the short-term transient response of the controller. The output of the load pulse amplifier is applied to the speed control summing point in droop mode. It is applied to the load matching circuit in isochronous mode.

In the load sharing mode, a bridge within the load matching circuit is connected in parallel with the bridges in other controls. When the load on the generator varies, an error signal is generated by the load matching circuit. This adjusts the load carried by the generator. LED indicators show the selection of isochronous and load sharing modes.

ISOLATION MODULE.—The isolation module provides buffering of the Woodward governor master frequency trimmer and Woodward governor SPM synchronizer signals. Also, the discrete logic signals for the overspeed test, reset to 60 Hz, raise, lower, isochronous, and load sharing control are buffered through isolators on this module.

SPEED REFERENCE MODULE.—The speed reference module generates the d.c. reference signal used by the speed control module. The reference values are selected by inputs from the switchboard or the EPCC. When the command is made to change frequency, a digital counter within the speed reference starts to count. It counts in an increasing or decreasing direction toward the new reference level. The counting process continues until the input command to change frequency is present. It continues until the new reference level is reached. The output of the counter is applied to a digital-to-analog converter. The converter changes the digital output of the counter to the output analog speed reference voltage. The speed reference module indicators show when it is at the reset, lower, or upper limits. They also show when they are moving.

SPEED CHANNEL MODULE.—The speed channel module maintains turbine speed at the value selected by the operator. A magnetic pickup (MPU) provides an a.c. signal that is proportional to turbine speed. The frequency sensor circuits convert the MPU signal to a proportional d.c. turbine speed signal. The speed control compares the actual turbine speed signal with the reference signal. The speed control amplifiers then generate a voltage signal to maintain or correct turbine speed. The speed control loop has the following inputs.

- Master frequency trimmer
- Synchronizer
- Frequency sensor
- Speed reference signal
- Load sensor

These speed error signals are input to the summing point. The stability amplifier applies the summed signal to the speed control gain amplifier.

The control amplifiers provide proper transient response of the turbine. The stability amplifiers control the time required to recover from a transient. The gain amplifiers control the amplitude of the transient. Correct adjustment is achieved when the time and off speed are both minimized without turbine instability.

The output for the speed control circuit is applied to the low-signal select (LSS) bus. The LSS bus has diode inputs from the speed, temperature, LSS bus maximum limit clamp, and the fuel filter control amplifiers. The bus allows the lowest signal input to dominate the bus. The output of the LSS bus is applied to the input of the high-signal select (HSS) bus. A speed control feedback signal is used so the control amplifier can anticipate control of the LSS bus. This provides smooth, bumpless transition between control channels without excessive overshoot.

POWER SUPPLY MODULE.—The power supply module provides isolated d.c. power for the control circuits. The power supply converts 28 volts d.c. to +12 volts d.c. and +R and −R precision reference voltages for use by the control circuits. The +12 volts d.c. and −12 volts d.c. voltages power the control electronics. The +R and −R voltages are reference voltages where precise voltages are required. The d.c. voltages are distributed to the modules by the motherboard. During maintenance on the governor system, a jumper wire must be used between two designated test points. This enables the LEDs on the circuit cards to illuminate.

FUEL LIMITER MODULE.—The fuel limiter module contains the circuits required during turbine start-up and acceleration. The start fuel schedule circuit controls the fuel flow to the turbine during start-up. It monitors three signals from the turbine—first TIT, second CIT, and third N_1 (speed voltage). CIT and N_1 together

produce corrected speed. Corrected speed is the voltage from the speed frequency sensor corrected by the CIT temperature. Speed correction results in increased fuel as CIT decreases. Start fuel is decreased as a function of TIT. More fuel is required for start-up than for acceleration at correct temperatures.

The output from the start fuel schedule is applied to the HSS bus. The HSS bus is a comparator circuit. It allows the highest signal applied to the bus to pass. The other input to the HSS bus is the fuel limiter circuit. The fuel limiter limits the maximum amount of fuel to the turbine as a function of speed. At rated or isochronous speed, fuel is limited by the mechanical stop on the fuel valve. When turbine speed is in the low-speed range, the fuel limiter signal is less than the start fuel schedule. So the fuel limiter signal is not selected by the HSS bus. The output from the HSS bus is applied to the fuel limiter amplifier. This amplifier then drives the LSS bus when its voltage is less than the speed or temperature control inputs. The fuel limit mode LED shows when the fuel limiter module is controlling fuel.

The fuel limiter module has a deceleration limiter circuit. The deceleration limiter controls the minimum fuel flow to the turbine. If fuel is decreased too rapidly, a flameout will occur. During start-up, the output of the LSS bus is high-signal selected. It has a fixed voltage when the engine speed is below 8400 rpm. This voltage limiter prevents the fuel valve from reaching the minimum fuel flow stop during start-up.

The acceleration temperature reference voltage increases as the turbine speed increases during acceleration. A CIT bias sets the reference lower as the ambient temperature decreases. An 8400-rpm speed switch and a start/run latch are used to select the temperature channel operating reference. Below 8400 rpm the latch is set to the start mode. This selects the acceleration temperature reference and start TIT LED. When the speed switch is above 8400 rpm and speed control has been achieved, the start/run latch is set to run. The run indicator LED lights up.

TEMPERATURE CHANNEL MODULE.—The temperature channel prevents turbine temperature from exceeding safe operating limits. A signal proportional to TIT is compared with the start or run temperature reference. The amplifier generates a voltage signal output to the LSS bus to limit TIT.

The temperature control amplifiers operate similar to the speed control amplifiers. Separate start and run LEDs are provided. They compensate for the longer thermocouple time constant at low turbine speeds. This lag is due to low airflow at low speeds.

A start fuel schedule supplies enough fuel for TIT to reach the acceleration temperature range (4000-5000 rpm). When the turbine reaches the acceleration range, the temperature control requires less fuel than the fuel limiter. The LSS bus then selects the temperature control for the rest of turbine acceleration.

When the turbine reaches isochronous or rated speed (60 Hz), the speed control takes control from TIT control. Then the start/run reference switches to run limit. TIT is a function of load on the turbine. If load is increased until TIT equals the TIT reference, the temperature control will maintain TIT at that level. In droop mode or when paralleled with other units, the generator load will be maintained at a level to produce the set TIT. When no other source is available to carry the excess load, the temperature control will reduce speed.

FINAL DRIVER MODULE.—The final driver module generates current to position the actuator as required by the controlling channel. An oscillator generates an excitation voltage for the LVDT located on the LFV. As mentioned before, the LVDT is mechanically linked to the fuel valve metering sleeve. It senses the fuel valve position. This sleeve is moved through the action of the actuator. As it moves, the excitation voltage transmitted to the LVDT output is changed. The output of the LVDT is proportional to the position of the fuel metering sleeve. A demodulator in the final driver changes the LVDT feedback signal to a d.c. voltage. This voltage is proportional to the sleeve position on the fuel valve. The final driver amplifier compares the input from the control circuits with the LVDT voltage. Then it correctly positions the fuel valve. The final driver and actuator are reverse acting. The less current supplied to the actuator, the greater the fuel supplied to the turbine.

MOTHERBOARD.—The motherboard's primary function is to interconnect the eight daughter boards with each other and the J1, J2, and J3 receptacles. The motherboard also has the power drive transistor for the actuator. This transistor is mounted on a heat sink which is connected to the chassis.

GTGS LOCAL OPERATING PANEL

The local operating panel (LOCOP) is the major operator interface with the GTGS. It has the controls and indicators necessary to start, stop, motor, and monitor GTGS operation. The LOCOP is also the interface with the ECSS which provides control of each GTGS at the EPCC. Many of the indicators available at the GTGS LOCOP are not available at the EPCC. This requires personnel to monitor the LOCOP during GTGS operation. Usually this monitor is a junior GS. For this reason, you should know and become very familiar with the material in this section.

Two LOCOPs are used to control the two different GTGS models. Their construction is radically different. They are made by two different manufacturers. Even though they are so different, they provide the engine and the operator almost identical signals and data. Their main difference lies in the method in which their data and signals are provided.

MODEL 104 LOCOP

The Model 104 LOCOP is contained in a cabinet mounted on the generator end of the module. On the outside of the cabinet doors are the controls and indicators for local GTGS operation. Inside the cabinet are the electronic components of the system. Among these components are printed circuit cards, voltage regulators, minus 24-volt d.c. converter module, a relay assembly, and a temperature and speed control unit. The control elements of the system are powered by 28 volts d.c. from the switchboard. The switchboard 28-volt d.c. supply has a bank of 15 amp-hr lead-acid batteries for backup. This battery bank allows starting of a GTGS when the ship is without 450-volt a.c. power.

Control Panel Layout

The following five sections detail the layout of the Model 104 LOCOP (figure 8-33). The letters after each item discussed correspond to the letters on figure 8-33.

MONITORING AND INDICATING INSTRUMENTS:

1. Generator air temperature meter (A)
2. Generator bearing temperature meter (with selector switch to select either bearing) (B)
3. Generator stator temperature meter (with selector switch to select any one of six temperature detectors) (C)
4. Enclosure temperature (turbine enclosure) (D)
5. HP start cycle counter (E) and LP start cycle counter (F)
6. Lube oil header pressure (reduction gear header) (G)
7. Engine rpm (H)
8. Running time (I)
9. Lube oil temperature (reduction gear header) (J)
10. Turbine inlet temperature (K)
11. Turbine vibration (L)

ALARM INDICATIONS WITH ENGINE SHUTDOWN:

1. FAIL TO FIRE—Failure to attain 600 °F TIT within 10 seconds after speed exceeds 2200 rpm (M)

2. START OVERTEMP—TIT greater than 1600 °F at speeds below 12,780 (N)

3. ENGINE OVERTEMP—TIT greater than 1945 °F at speeds above 12,780 rpm (O)

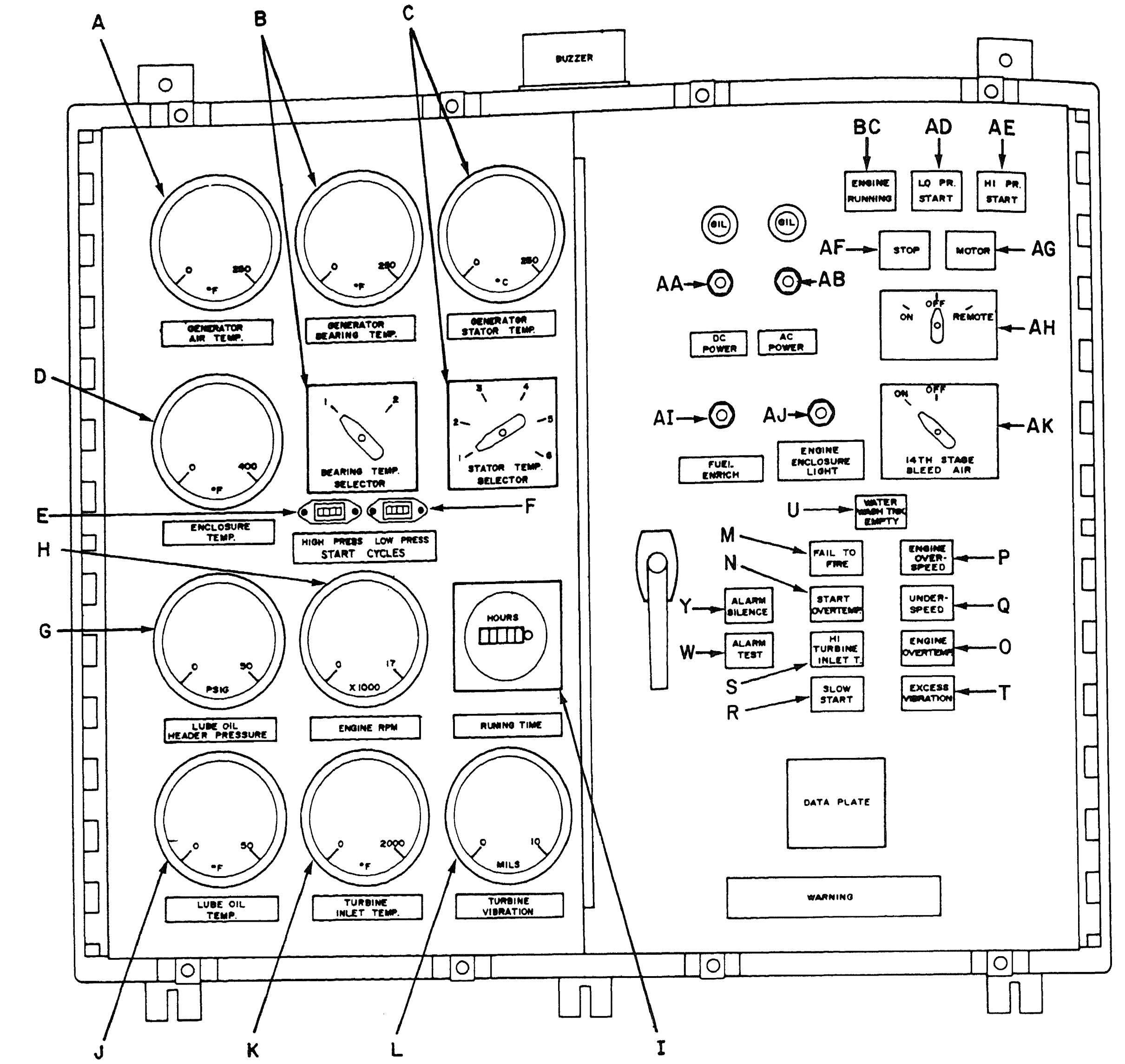

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Figure 8-33.—Model 104 LOCOP.

4. ENGINE OVERSPEED—Speed greater than 15,800 rpm (P)

5. UNDERSPEED—Speed below 12,780 rpm after having been above 12,780 rpm for 2 seconds (Q)

When engine shutdown occurs because of these abnormal conditions, the control system will prevent restarting. It prevents restarting until the alarm condition no longer exists and the 2-minute coastdown timer has expired.

ALARM INDICATIONS ONLY:

1. SLOW START—Failure of engine to reach 12,780 rpm within 2 minutes after start initiation (R)

2. HI TURBINE INLET—TIT greater than 1880°F at speeds above 12,780 rpm (S)

3. EXCESS VIBRATION—Turbine vibrations in excess of 3 mils peak-to-peak at a frequency above 140 Hz (T)

OTHER ALARM DISPLAYS AND FUNCTIONS:

1. Turbine WATER WASH TANK EMPTY (U).

2. ALARM SILENCE Pushbutton. When an alarm condition occurs, corresponding indicators flash red and a buzzer is energized. The alarm silence pushbutton also lights up red. When depressed, the buzzer is silenced and the indicated alarm light becomes steady red. When the abnormal condition no longer exists, the alarm indicator will turn off automatically (V).

3. ALARM TEST Pushbutton. When depressed, it will cause all alarm indicators to flash and the buzzer to sound. The alarms are then reset with the alarm silence pushbutton. This test assures you that the alarm indicators and alarm logic circuits are fully operative (W).

When the engine is operating with TIT greater than 1600°F and a shutdown occurs because of underspeed, the UNDERSPEED indicator will flash and the START OVERTEMP indicator will light up steady. This condition remains true until the alarm silence pushbutton is depressed, and the abnormal conditions no longer exist. This function shows you the abnormal condition that actually caused the shutdown.

CONTROL INDICATORS AND PUSHBUTTONS:

1. DC POWER (on-off toggle switch)—Provides all power necessary to start and run the gas turbine (AA).

2. AC POWER (on-off toggle switch)—Provides 115 volts, 60 Hz for enclosure lights and running time meter (AB).

3. ENGINE RUNNING Indicator—Illuminates at speeds above 12,780 rpm (AC).

4. LO PRESS START (low-pressure start pushbutton/indicator—Provides for engine starting on the bleed air system (normal) (AD).

5. HI PRESS START (high-pressure start pushbutton/indicator)—Provides for engine starting on the HP system (emergency) (AE).

6. STOP—Provides for stopping the engine regardless of the ON-OFF-REMOTE selector switch position (AF).

7. MOTOR—Provides for motoring the engine regardless of the ON-OFF-REMOTE selector switch position (AG).

8. ON-OFF-REMOTE Selector (AH).

ON—Enables LP and HP start pushbuttons on enclosure door.

OFF—Prevents starting of engine from any location.

REMOTE—Transfers only start control functions to the associated switchboard and/or the EPCC (local indicators, alarms, stop, and motor function remain operative).

9. FUEL ENRICH (on-off toggle switch)—Provides for cold weather starting of engine (AI).

10. ENGINE ENCLOSURE LIGHT (on-off toggle switch) (AJ).

11. 14TH-STAGE BLEED AIR (on-off selector switch)—ON position enables the control system that opens, regulates, and closes the 14th-stage bleed air valve (AK).

Model 104 LOCOP Electronics

The equipment mounted inside the LOCOP has fuses, power supplies, relays, a 28-volt d.c. powerline filter, logic cards, signal conditioning cards, alarm cards, solenoid driver cards, contact buffer cards, a vibration card, and the

temperature and speed control box. Figure 8-34 shows the internal layout of the LOCOP.

Both 115 volts a.c. and 28 volts d.c. are required for normal operation of the LOCOP. However, the GTGS may be started with only the 28-volt d.c. supply. The GTGS enclosure lights are energized through cabinet door interlock relay contacts and the ENGINE ENCLOSURE LIGHT switch. The running time meter is energized through cabinet door interlock relay contacts, the AC POWER switch, and relay contacts. The contacts close when the GT is running. All the 115-volt a.c. circuits are protected by the F1 and F2 (15 amp) fuses. The +28 volts d.c. electronic circuits are supplied through a powerline filter, F3 (20 amp) fuse, and the DC POWER switch. The ignition exciter is supplied through the F4 (10 amp) fuse and contacts of a relay operated from the logic circuits.

Conversion of the 28-volt d.c. power to the voltage levels needed by the logic is done by a +15 and −15 volts regulator, a −24 volts converter, and a +5 volts regulator.

The −24 volts converter uses a transistorized and zener diode controlled oscillator. It is fed by the +28 volts d.c. supply. The oscillator output is a transformer coupled to a full-wave bridge rectifier. After filtering, the unregulated −24 volts d.c. is used as an input to the −15 volts d.c. regulator (adjustable). This regulator is on the same printed circuit board as the +15 volts d.c. regulator. It is fed from the +28 volts d.c. source.

The circuit cards are of several different types.

1. Relay (or solenoid) drivers energize relays or solenoids in response to a signal from a logic unit. They are used because the relay and solenoid coils require more current than can be supplied directly from a logic unit.
2. Contact buffers minimize the effect of contact bounce (due to operation of pushbutton or relay contacts) on a logic input.
3. RTD signal conditioners convert generator stator, air, lube oil, and bearing temperatures to signals used for local and remote monitoring.
4. The RTD/pressure signal conditioner converts engine enclosure temperature and lube oil header pressure to signals for local and remote monitoring.
5. A set point 1850 to 1870°F card converts TIT signal from the speed temperature control unit for control of the 14th-stage bleed air valve.
6. The vibration signal conditioner is a special card. It is used to convert the signal from a vibration pickup unit to a signal for local and remote monitoring and alarm.
7. Logic cards sequence the various events during a turbine start and/or stop.
8. Alarm cards initiate turbine shutdown and local alarms for abnormal turbine operating conditions.
9. The alarm control card controls alarm light flashing and buzzer energizing.

Turbine Temperature and Speed Control Box

The turbine temperature and speed control is a combination electronic speed switch and temperature amplifier. It is mounted in the LOCOP. The control receives a speed signal from a magnetic pickup on the PTO shaft and a temperature signal from the turbine inlet thermocouples. These signals position control relays in four speed channels and five temperature channels within the box. They also provide signals for local and remote monitoring of speed and TIT. In combination with logic circuitry described in the last section, the four speed channels and five temperature channels provide the functions as described below.

2200 RPM SPEED CHANNEL:

1. Energizes the ignition circuit.
2. Energizes the fuel shutdown valve solenoid (open).
3. Energizes the fuel pump paralleling valve solenoid (closed) to place the fuel pump HP primary and secondary elements in parallel operation.
4. Energizes the fuel enrichment valve solenoid. The valve will open if fuel enrichment has been selected. When manifold pressure reaches 50 psig, the fuel enrichment valve solenoid will de-energize, closing the valve.
5. De-energizes the start temperature limit valve solenoid, closing the drain port and opening the pressure port to the LFV acceleration control section.

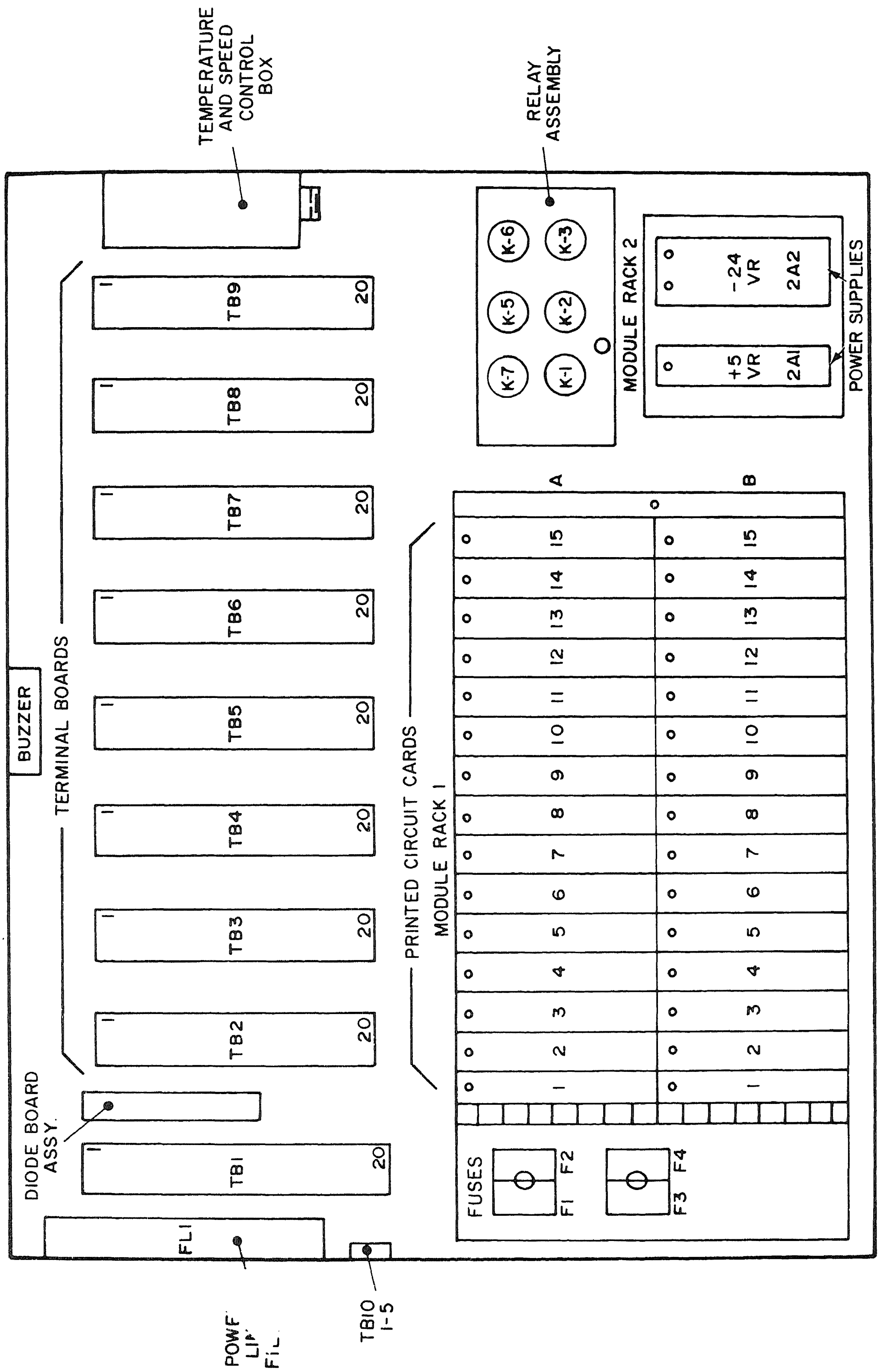

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Figure 8-34.—LOCOP internal layout.

6. Arms the start temperature limit valve control to cycle the start temperature limit valve solenoid (on and off) to reduce TIT if it exceeds 1500 °F.

7. Starts the 10-second fail-to-fire timer. If TIT fails to reach 600 °F through the 600 °F temperature channel before the timer elapses, the fail-to-fire circuit will initiate an automatic shutdown.

8. Energizes the running time meter relay to start the meter.

8400 RPM SPEED CHANNEL:

1. Inhibits the fuel paralleling valve, enrichment valve, and ignition circuits to prevent reactivation during a shutdown.

2. De-energizes the ignition circuit.

3. De-energizes the fuel pump paralleling valve solenoid (open) to place the HP fuel pump primary and secondary elements in series operation.

4. De-energizes the LP (or HP) start air valve solenoid (closed) to cut out the starter.

5. Extinguishes the LP (or HP) start pushbutton indicator.

6. De-energizes the GTM HP start inhibit relay if the GTGS was started on HP air. Allows GTM in same engine room to be started on HP air.

12,780 RPM SPEED CHANNEL:

1. Inhibits the start temperature limit valve control circuit to permit TIT to increase above 1500 °F.

2. Inhibits the start overtemperature shutdown circuit to permit TIT to increase above 1600 °F.

3. Arms the engine overtemperature shutdown circuit to shutdown the turbine if TIT increases to 1945 °F.

4. Inhibits the slow start alarm circuit.

5. Starts the 2-second underspeed timer. When elapsed, it will arm the underspeed shutdown circuit to automatically shut down the turbine. This happens if speed decreases below 12,780 rpm during operation.

6. Lights up the ENGINE RUNNING indicator light.

7. Enables the 14th-stage bleed valve control circuit to permit opening of the valve (when selected) as long as TIT is not greater than 1850 °F. Once opened below 1850 °F, the valve will remain open until TIT reaches 1870 °F. At this point the valve will start closing to try to hold TIT below 1870 °F. When TIT drops below 1870 °F, the valve position will stabilize at an interim position. The valve will not close further until TIT again reaches 1870 °F. It will not completely open again until TIT drops below 1850 °F. If TIT remains above 1870 °F, the valve will fully close. It will remain closed until TIT decreases below 1850 °F.

15,800 RPM SPEED CHANNEL: Provides engine overspeed protection. If engine speed exceeds 15,800 rpm, an automatic shutdown is initiated.

600 °F TEMPERATURE CHANNEL: Provides automatic shutdown if 600 °F TIT is not reached within 10 seconds after reaching 2200 rpm.

1500 °F TEMPERATURE CHANNEL: Activates the start temperature limit valve control circuit. The circuit intermittently energizes the start temperature limit control valve solenoid through a pulse timer. This reduces acceleration fuel flow, and thereby reduces TIT below 1500 °F.

1600 °F TEMPERATURE CHANNEL: Starts an automatic shutdown if 1600 °F TIT is reached below 12,780 rpm.

1880 °F TEMPERATURE CHANNEL: Causes an alarm to sound if 1880 °F TIT is reached.

1945 °F TEMPERATURE CHANNEL: Starts an automatic shutdown if 1945 °F TIT is reached above 12,780 rpm.

MODEL 139 GTGS LOCOP

The Model 139 LOCOP provides start/stop sequencing for the GTGS, monitoring and alarms for critical turbine and generator parameters, and signal conditioning for panel meters and transmission of selected data to the ECSS.

The LOCOP is contained in a cabinet mounted on the generator end of the module. On the outside of the cabinet doors are the controls and indicators for local GTGS operation. Inside the cabinet are the electronic components of the system. Among these components are printed circuit cards, voltage regulators, a ±12 volts d.c. converter module, a relay assembly, and a temperature and speed control unit. The control elements of the system are powered by 28 volts d.c. from the switchboard. The switchboard 28-volt d.c. supply has a bank of 15 amp-hr lead-calcium batteries for backup. This battery bank allows starting of a GTGS when the ship is without 450-volt a.c. power.

Control Panel Layout

The following section details the layout of the Model 139 LOCOP (figure 8-35, a foldout at the end of this chapter). The letter or letter/number combination with each item corresponds to the location of the item on figure 8-35.

Model 139 LOCOP Electronics

The Model 139 LOCOP is a computer controlled digital system. It uses a central microprocessor to control and monitor the GTGS. Figure 8-36 shows the internal layout of the parts of the Model 139 LOCOP. The LOCOP has the necessary power supplies to power all logic and switching level voltages.

The LOCOP system power supply printed circuit card and associated heat sink are mounted on the left side of the LOCOP cabinet. The system has the following components.

1. A d.c.-d.c. converter that supplies ±5 volts d.c. and ±15 volts d.c.

2. A switching power supply that supplies ±12 volts d.c. and ±10 volts d.c.

3. A switching power supply that supplies ±5 volts d.c.

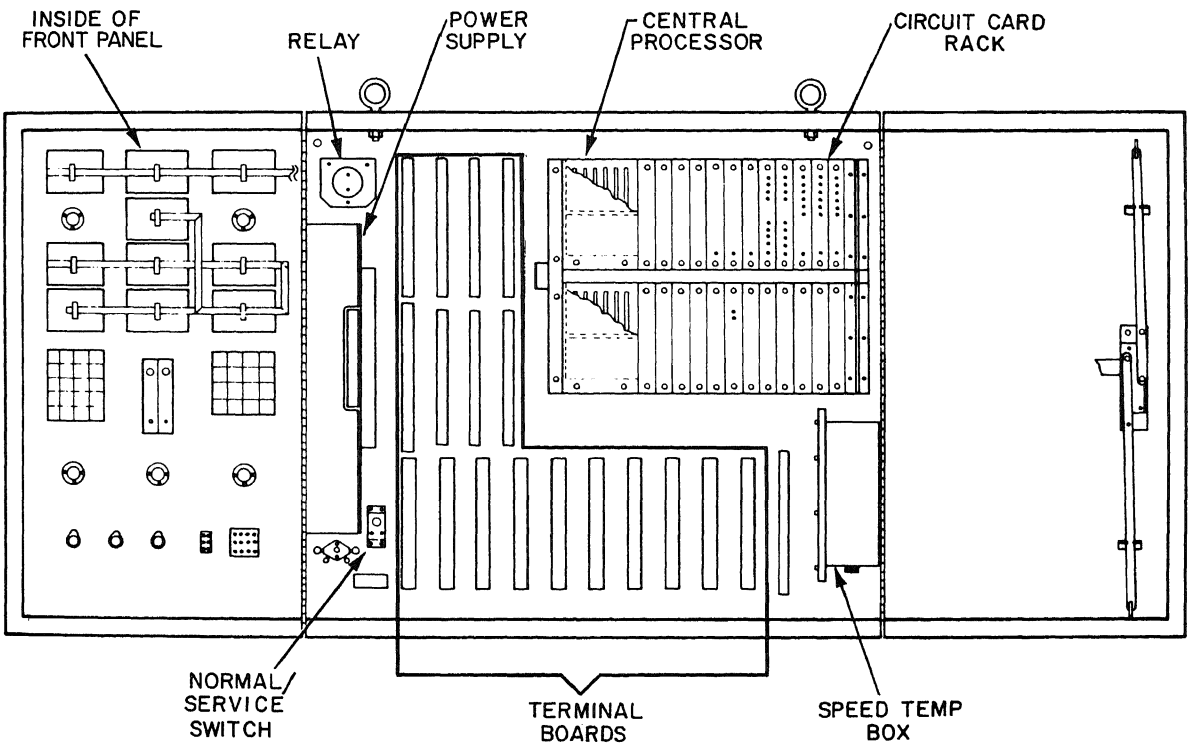

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Figure 8-36.—Model 139 LOCOP internal layout.

The audible alarm system has a printed circuit card where six different audible signals are electronically generated. Any one of the six are programmably selected. The selected signal is then amplified by the alarm amplifier assembly. The amount of amplification is adjustable to fit the environment. The printed circuit card is mounted in the card rack. The alarm amplifier assembly and speaker are mounted on the right side of the LOCOP cabinet.

For general description purposes, we have grouped the LOCOP electronics into their associated tasks.

CPU, MEMORY, I/O INTERFACE.—These three cards make up the system computer control. The CPU card has the microprocessor. The memory card has the system control program and data storage memory space. The I/O interface card provides the link between the computer control and the outside world. The LOCOP has two computer control systems for faster, more efficient control of the GTGS and for backup purposes.

BUS CONTROLLER.—This card generates the system's real time clocks and the synchronization signals. These are required to allow the two computer control units to operate together.

I/O MEMORY.—This card has data storage memory space. It is independent of the computer control memory. This memory may be used by either computer control system where data needs to be shared between them.

CONTACT BUFFER.—This card has 16 inputs to interpret a switch closure. Electronics are included to interrupt the microprocessor so the special task requested by the switch can be handled. The card may be programmed to accept normally open or closed contacts. It will interrupt the microprocessor on both transmissions of the switch. There are two cards per LOCOP system.

SWITCH BUFFER.—This card has eight inputs to interpret a switch closure. It differs from the contact buffer by interrupting the microprocessors only upon initial closure. The switch release is not buffered. There are two cards per LOCOP system.

LAMP DRIVER.—This card has eight output driver circuits used to illuminate the visual indicators on the LOCOP front panel. The indicators can burn steadily or flash depending on the control program. There is also circuitry. If a lamp fails, the microprocessor will be interrupted to indicate an internal failure. There are three cards per LOCOP system.

RELAY CONTROL.—This card has eight relays, all independently controlled by the control program. Each relay provides normally open and normally closed contacts. There is also circuitry to detect a failure of the driver circuits. The circuits will interrupt the microprocessor to indicate an internal failure. There are two cards per LOCOP system.

SOLENOID DRIVER.—This card contains six solenoid driver circuits. All are independently controlled by the control program. There is circuitry to detect a failure of the driver circuits or a shorted solenoid. This will interrupt the microprocessor to indicate an internal failure.

DISPLAY CONTROL/DIGITAL METER.—This card receives, from the computer control, the digitized monitor data. It then directs this data to the associated digital display card located on the LOCOP front door. Up to 16 channels may be handled.

ANALOG TO DIGITAL CONVERTER (ADC), DIGITAL TO ANALOG CONVERTER (DAC).—These three cards make up the monitor data handling system of the LOCOP. The analog input/multiboard has eight input circuits with 10-mA output current sources. These inputs are designed to accept 0 to 10 volts d.c. The data can be attenuated or amplified by electronics or the control program. Once conditioned, this card multiplexes the data to be digitized by the ADC card. The digitized data is then sent to the I/O memory card for storage. The control program then conditions this data for the digital displays and analog output card. The analog output card can convert up to eight channels of data to a 0- to 10-volt d.c. signal. This analog signal can be used depending on the control program. There are two analog input cards, two analog output cards, and one ADC card per LOCOP.

VIBRATION MONITOR.—This card monitors the engine vibration pickup and scales it for control purposes. The card also splits the signal and sends it to the remote monitor outputs and analog input card. Also an electronic switch circuit detects high vibration. It signals the microprocessor control via a contact buffer input.

ALARM BOARD.—This card generates the alarm tones required for the audible alarm system. Six tones are possible. There is also circuitry to adjust the volume of the audible alarm.

I/E CONVERTER.—This card converts the 4- to 20-mA pressure transducer current outputs to 0 to 10 volts d.c. Buffer circuits enable multiple outputs of these signals as well as RPM and TIT signals. There is also circuitry to calibrate the RPM/TIT analog meter on the LOCOP front panel. An electronic switch closure is adjustable for any predetermined RPM set point.

ALLISON SPEED/TEMP CONTROL BOX.—This unit, supplied by Allison, generates switch closures required by the computer control system to control the GTGS. These include engine speed as well as engine TIT set points. The unit also supplies the signals for the analog RPM/TIT meter located on the LOCOP front door.

The speed and temperature channels on the Model 139 are almost identical to the channels used on the Model 104 set. There are a few exceptions as follows.

- Fuel enrichment is not used so it is not enabled at 2200 rpm.

- The start temperature limit control valve is not used on the Model 139. No signal is sent to it at 2200 rpm or 12,780 rpm.

- During start above 2200 rpm, the engine must accelerate at a rate of 40 rpm/second over any 3-second period. When this is enabled by the 2200-rpm speed channel, and the engine fails to accelerate at that rate, an antistagnation feature will shut down the engine and sound the slow start alarm.

- The 1945 °F temperature channel has been reset to 2050 °F. This is to allow for higher load transients. The 1880 °F temperature channel remains the same.

GTGS STARTING AND STOPPING

Both Model GTGSs have a fairly common start/stop sequence. The major difference is found in fuel control during starting. The Model 104 GTGS accelerates using the start temp limit control valve and LFV to control the fuel schedule. The Model 139 accelerates using the governor for fuel scheduling to engine run. Because of this difference, we will describe the sequence for the Model 104 and discuss where differences lie in the Model 139.

AUTOMATIC START/STOP

The GTGS control system provides the automatic start sequencing logic, monitoring of critical parameters, and alarm shutdown functions. A logic flow diagram of the start sequence is shown in figure 8-37. Following is a description of the events that occur.

Start Initiation

Momentarily press the LOW (or HIGH) PRESSURE START pushbutton switch. The engine may be started from either the LP or HP air system. The respective air systems must have been previously aligned. The normal start system is LP air (bleed air). Emergency start system is HP air.

1. The stop pushbutton switch will extinguish. The LOW (or HIGH) PRESSURE START pushbutton will illuminate.
2. The LP (or HP) air solenoid will energize. During an HP start of No. 1 or No. 2 GTGS, the GTM HP start inhibit relay will energize. This inhibits the HP start of a GTM within the same engine room.
3. The LP (or HP) air start cycle counter will advance one number.
4. The start temperature limit valve solenoid is energized. The pressure port closes and the drain opens. This allows the GTGS to start

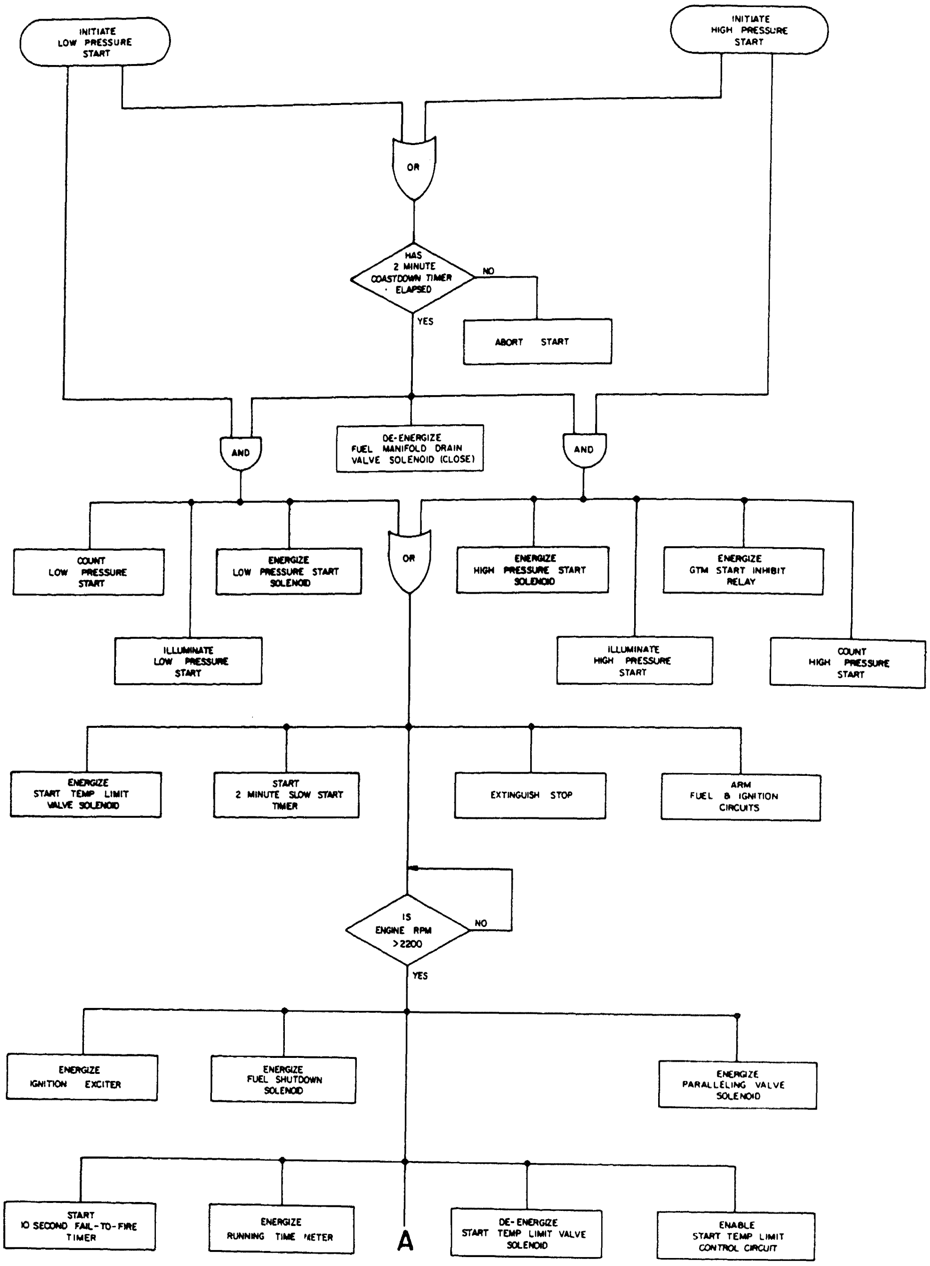

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Figure 8-37.—GTG start sequence flow diagram.

on the minimum fuel setting. (Not on the Model 139.)

5. The fuel and ignition circuits are armed.

6. The 2-minute slow start timer is energized.

Acceleration Under Starter Power

The engine accelerates under starter power. At 2200 rpm the following conditions occur.

1. The ignition system is energized.

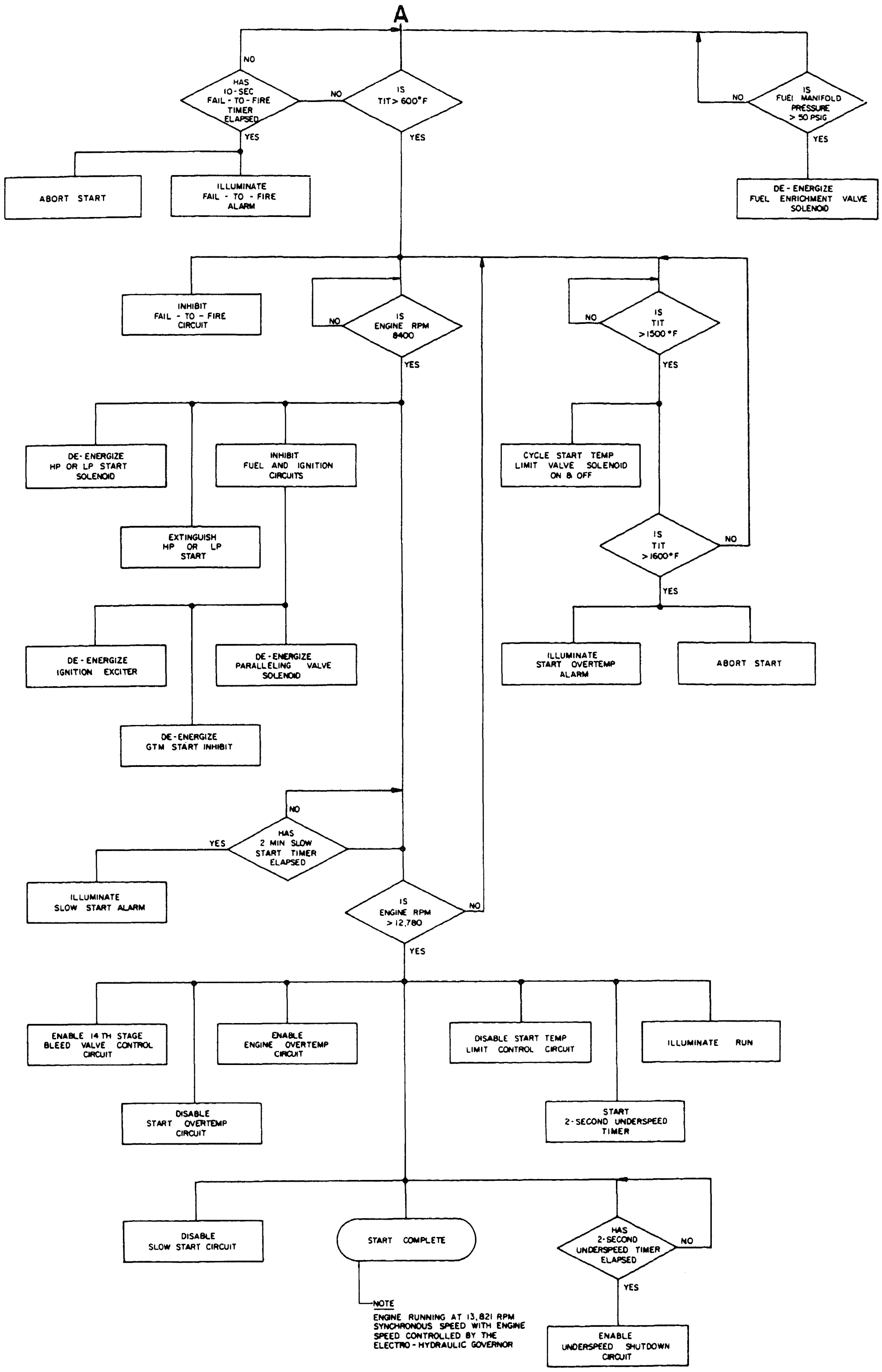

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Figure 8-37.—GTG start sequence flow diagram—Continued.

2. The fuel shutdown valve solenoid is energized (opened).

3. The fuel pump paralleling valve solenoid is energized (closed). This places the fuel pump HP primary and secondary elements in parallel operation.

4. The fuel enrichment valve solenoid is energized (opened) if fuel enrichment has been selected. When fuel manifold pressure reaches 50 psig, the fuel enrichment valve solenoid will de-energize. This closes the valve. (Not used on the Model 139).

5. The start temperature limit valve solenoid will de-energize. The drain port closes and the pressure port opens to the acceleration control section. The turbine will be accelerated at a rate equal to CDP increase modified by CIT. (Not used on the Model 139.)

6. The start temperature limit valve control circuit is armed. If TIT reaches 1500 °F, the start temperature limit valve control circuit will intermittently energize the start temperature limit valve solenoid. It does this through a pulse time. This reduces acceleration fuel flow, and thereby reduces TIT below 1500 °F. (Not used on the Model 139.)

7. The 10-second fail-to-fire timer is started. If TIT fails to reach 600 °F through the 600 °F temperature channel before the timer elapses, the fail-to-fire circuit will start an automatic shutdown. If 600 °F TIT is reached before the timer elapses, the fail-to-fire shutdown circuit is inhibited.

8. The running time meter is energized.

9. On the Model 139, the antistagnation circuit is enabled.

Acceleration Under Starter and Engine Power

The engine accelerates under starter and engine power. At 8400 rpm the following occurs.

1. The fuel paralleling valve, enrichment valve, and ignition circuits are inhibited. This prevents reactivation during a shutdown.

2. The ignition circuit is de-energized.

3. The fuel pump paralleling valve solenoid is de-energized (open). This places the HP fuel pump primary and secondary elements in series operation.

4. The LP (or HP) start air valve solenoid is de-energized (closed) to cut out the starter.

5. The LOW (or HIGH) PRESSURE START pushbutton/indicator will extinguish.

6. The GTM HP start inhibit relay will de-energize if GTGS was started on HP air. This allows the GTM in the same engine room to be started on HP air.

Acceleration Under Engine Power

The engine accelerates under turbine power. At 12,780 rpm the following occurs.

1. The start temperature limit valve control circuit is inhibited. This permits TIT to increase above 1500 °F during normal operation. (Not used on the Model 139.)

2. The start overtemperature shutdown circuit is inhibited. This permits TIT to increase above 1600 °F during operation.

3. The engine overtemperature shutdown circuit is armed. If TIT increases to 1945 °F (2050 °F in the Model 139), the circuit will initiate an automatic shutdown.

4. The slow start alarm circuit is inhibited.

5. The 2-second underspeed timer is started. When elapsed, the underspeed shutdown circuit is armed. If turbine speed decreases below 12,780 rpm after the 2-second time has elapsed, an automatic shutdown will be initiated.

6. The ENGINE RUNNING indicator light will illuminate.

7. The 14th-stage bleed valve control circuit is enabled. This permits opening of the valve (when selected) as long as TIT is not greater than 1850 °F. Once opened below 1850 °F, the valve will remain open until TIT reaches 1870 °F. At this point, the valve will start closing to try to hold TIT below 1870 °F. When TIT drops below 1870 °F, the valve position will stabilize at an interim position. The valve will not close further until TIT again reaches 1870 °F. It will not completely open again until TIT drops below 1850 °F. If TIT remains above 1870 °F, the valve will fully close. It will remain closed until TIT decreases below 1850 °F.

ALARM/SHUTDOWN FUNCTIONS

During operation, the GTGS control system provides the logic for the following alarm/shutdown functions.

1. Alarm only functions

   - SLOW START (shutdown on Model 139 for antistagnation)
   - HIGH TURBINE INLET TEMPERATURE
   - EXCESSIVE VIBRATION

2. Automatic shutdown and alarm functions

   - FAIL TO FIRE
   - START OVERTEMPERATURE
   - ENGINE OVERTEMPERATURE
   - ENGINE OVERSPEED
   - UNDERSPEED

3. Additional functions

   - Prohibits opening of the 14th-stage bleed air valve at speeds below 12,780 rpm.
   - Inhibits starting for 2 minutes after a shutdown to allow the unit to coast down. (Three minutes on the Model 139.)
   - Regulates 14th-stage bleed air valve to maintain TIT at less than 1870°F.
   - Provides analog information to the ECSS for alarm and data systems.

INSTRUMENTATION AND MONITORING INTERFACE WITH THE ECSS

Information sent to the ECSS may be conditioned in the LOCOP or it may be sent to the ECSS for processing. The following material describes the data that is used by the ECSS and how it is processed.

INFORMATION CONDITIONED BY THE LOCOP

The following signals are conditioned to a 0- to 10-volt d.c. level by the signal conditioner cards. They are then distributed to the ECSS.

1. Lube oil header pressure
2. Generator stator temperatures (No. 1 through No. 6)
3. Generator bearing temperatures (No. 1 and No. 2)
4. Lube oil temperature
5. Generator air temperature
6. Engine enclosure temperature
7. TIT
8. Engine rpm
9. Vibration
10. GTGS No. 3 start air temperature

INFORMATION DIRECT TO THE ECSS

The following signals from either pressure or temperature switches are sent directly from within the GTGS to the ECSS.

1. Generator/reduction gear lube oil pressure low alarm
2. Enclosure temperature high alarm
3. Generator air temperature high alarm
4. Generator bearing temperature high alarm (front and rear)
5. Generator stator temperature high alarm
6. Module fire
7. Reduction gear lube oil temperature high alarm
8. Fuel oil strainer ΔP high
9. Lube oil strainer ΔP high

GTGS SUPPORT SYSTEMS

The GTGS has several support systems that provide cooling water or air to permit engine operation. The GTGS must be able to operate without relying on the other ship's systems. (One exception to this is the fuel oil service system. However, head tanks are installed that allow several hours of generator operation without operating the fuel oil service system.)

SEAWATER SERVICE SYSTEM

Each GTGS has an independent seawater service system. These are for the lube oil coolers and

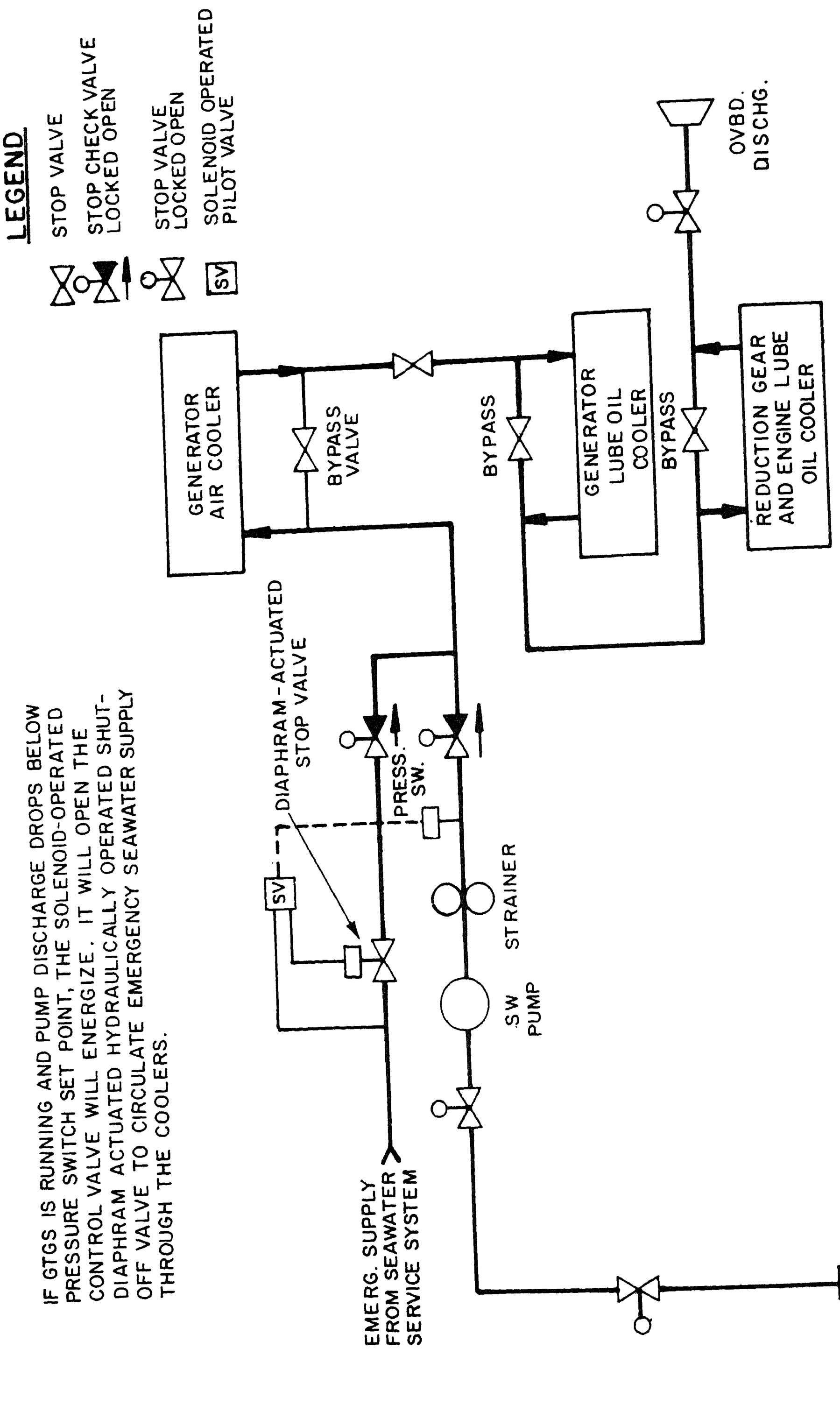

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Figure 8-38.—Generator seawater service system.

generator air cooler. An electric pump starts automatically as the generator voltage builds up. This is done because power is taken from the generator side of the main circuit breaker. If the electric pump system fails, emergency cooling water is supplied by the ship's seawater service system. Figure 8-38 is a flow diagram of this service system. A solenoid-operated pilot valve opens. It automatically opens the diaphragm activated, hydraulically operated stop valve when LP contacts close in the pressure switch in the normal service line. Cooling water is drawn from the sea chest. It flows through the generator air cooler and lube oil cooler. It then passes through the engine lube oil cooler. The seawater flow requirements are different for the three coolers. Therefore, each unit has a bypass valve to adjust seawater flowing through the cooler.

INTAKE AND EXHAUST SYSTEMS

The intake and exhaust systems (figure 8-39) provide the flow path for combustion and cooling

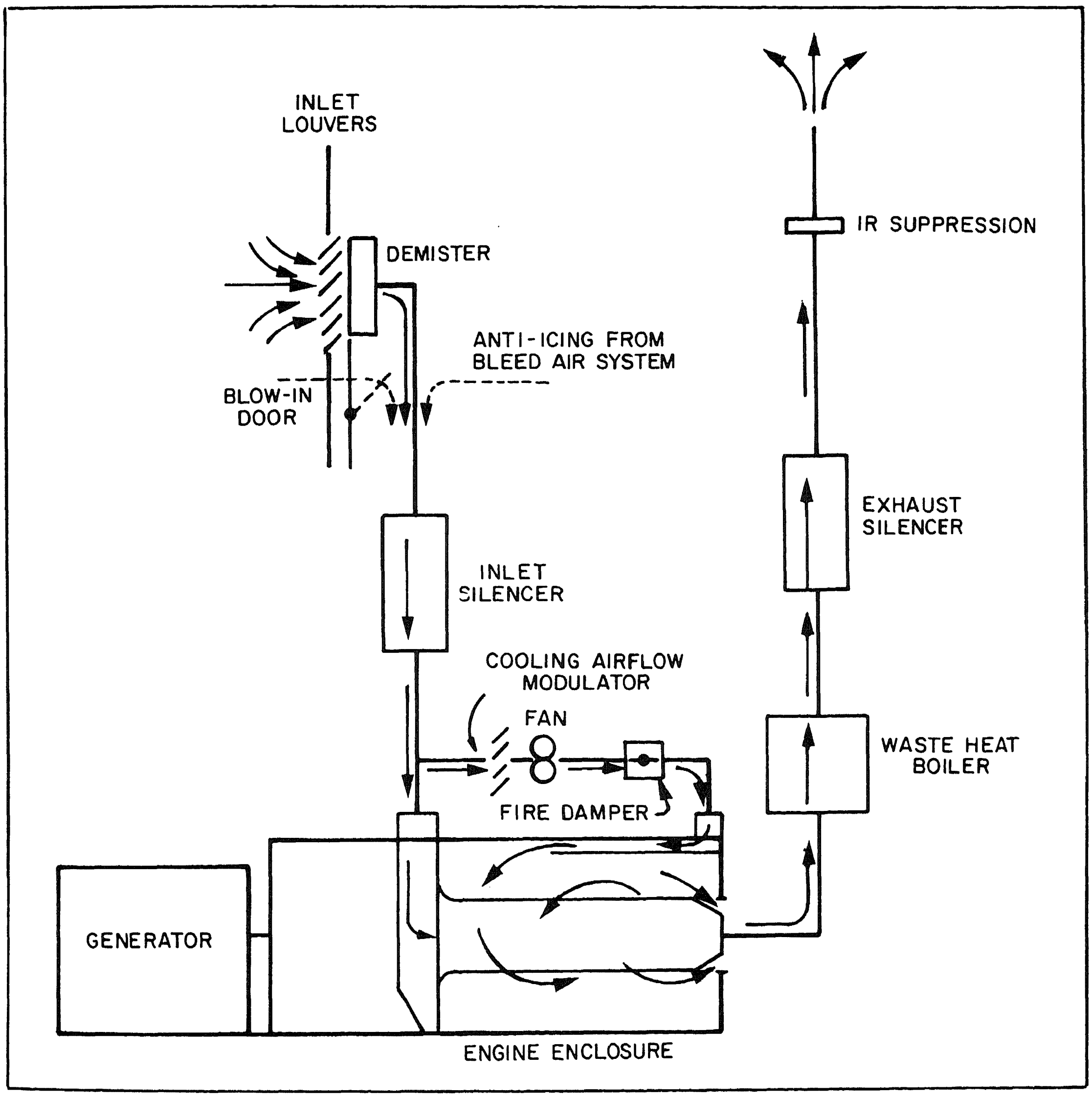

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Figure 8-39.—GTGS intake, cooling, and exhaust system.

air to the GT. They also provide for engine exhaust gas discharge. The inlet systems have inlet louvers, demisters, blow-in doors, silencers, cooling airflow modulators, fans, and fire dampers. The exhaust systems contain silencers and IR suppression systems. The exhaust gas from all three engines is routed through waste heat boilers before entering the exhaust stack.

Intake Duct

The intake ducts are rectangular structures. The ducts for the No. 1 and No. 2 engines are located in the inboard side of the exhaust stacks. Air enters the ducts through louvers mounted in the side of the stack. It flows through mesh pad type of demisters, through silencers, into the module inlet plenum, and into the engine inlet. The intake air inlet for GTGS No. 3 is located on the 01 level, starboard side, aft of the missile launcher area. Air enters a vertical bellmouth and flows downward into generator No. 3 inlet plenum. This plenum serves as a green water trap. It allows any large quantities of water to drain through slots in the deck combing. The air then flows through demisters into generator No. 3 intake room. The bulkhead between these two compartments has the blow-in doors. Combustion and cooling air flow through separate ducts from the intake room to the module.

Louvers

The intake duct inlets for the No. 1 and No. 2 engines have louvers similar to the main engine inlet louvers. Like the main engine louvers, they are designed and arranged to shed sea spray. Because of the vertical flow inlet design, the No. 3 engine duct inlet has no louvers.

Demisters

The demisters are mesh pad type. They are similar to those in the main engine inlet. They are arranged vertically behind the louvers. Moisture separated from the air collects in scuppers under the demisters and is drained overboard.

Blow-In Doors

A single blow-in door is located in each inlet below the demisters. Their purpose is to bypass the demisters if they become clogged. This permits enough combustion and cooling airflow to the engine for normal operation. A controller provides for manual or automatic operation by a selector switch on the controller door. When in manual, a pushbutton will energize a solenoid and release the blow-in door. When in automatic, the solenoid is energized by action of a pressure switch. This switch is set to operate at about 8 inches of water (in. H_2O) differential pressure. Indication and alarm of DUCT PRESS LO are given at PLOE and PAMCE. Once open, the doors must be closed manually.

Silencers

The vane-type silencers have sound deadening material encased in a perforated, stainless steel sheet. They are mounted vertically in the duct between the demisters and the cooling air duct.

Module Cooling

The module cooling system has a duct, an airflow modulator, an axial fan (two fans on the Model 139), a fire damper, an air silencer, and a ceiling-mounted baffle within the module.

FLOW MODULATOR.—The flow modulator is located in the cooling duct between the engine intake duct and the fan. It controls the flow of air to the module enclosure with respect to enclosure temperature. When the enclosure temperature increases to 180°F, the high temperature set point contacts of the module-mounted thermostat will close. This causes the flow modulator motor to rotate the modulating blade-type vanes to the full open position. When the enclosure temperature decreases to 170°F, the low temperature set point contacts will close. This causes the flow modulator motor to rotate the modulating vanes back to the half-open position. The modulator is not used on the Model 139 GTGS.

FAN.—The fan is located in the cooling air duct between the flow modulator and the fire damper. The fan draws air from the intake duct through the flow modulator. It blows the air through the fire damper to the module enclosure. Two fans are used on the Model 139. The air enters the module through the silencer. It passes down across the ceiling-mounted baffle within the enclosure. The air then circulates around the engine. It exits through a gap between the engine exhaust nozzle and the exhaust eductor section. There it mixes with the engine exhaust.

COOLING FAN CONTROLLER.—The fan controller is provided with a NORMAL/ALTERNATE power supply selector switch. It has a circuit to cycle the fan on and off automatically with respect to enclosure temperature. There is also circuitry to perform a GTGS system fire stop which is described later in this chapter. The NORMAL source for the controller is the generator bus; the ALTERNATE source is one of the other two switchboards. The fan will cycle on when a temperature switch within the module enclosure senses a temperature of 175 °F. It cycles off when the temperature decreases to 160 °F. The Model 139 cycles on and off with respect to temperature also, but this is controlled by the LOCOP.

FIRE DAMPER.—The fire damper is located in the cooling air duct between the fan and module enclosure. It closes off the flow of cooling air to the module when a fire is present within the module. During normal operation, the fire damper is held in the full open position. This is done by a motor mounted on the fire damper assembly. A fire may be detected by either of the two UV detectors within the enclosure. If this happens, the fire stop circuit within the fan controller will close a set of contacts. This energizes the fire damper motor and rotates the damper to the closed position.

Anti-Icing

The anti-icing system is similar to that in the main engine inlet ducts. That is, hot bleed air from the engine is discharged into the inlet duct. There it mixes with the inlet air and raises the temperature above the freezing point. Bleed air flow is regulated as a function of upstream temperature versus a fixed temperature. This maintains an inlet temperature of about 38 °F when anti-icing is selected. This temperature is enough to prevent the formation of ice. It also melts any ice, sleet, or snow entrained in the air.

Exhaust Duct

The exhaust ducts are round, insulated, stainless steel structures. Each duct has a silencer and an IR suppression system. The Model 139 uses a BLISS-type IR suppression system similar to the ones used on the CG-47 main engines. Because of their small size and low gas flow rate, they do not require eductors as do the main exhaust ducts. The exhaust ducts from the No. 1 and No. 2 engines run parallel to the main engine ducts in the exhaust stacks. The duct from the No. 3 engine (figure 8-40) traverses the ship and

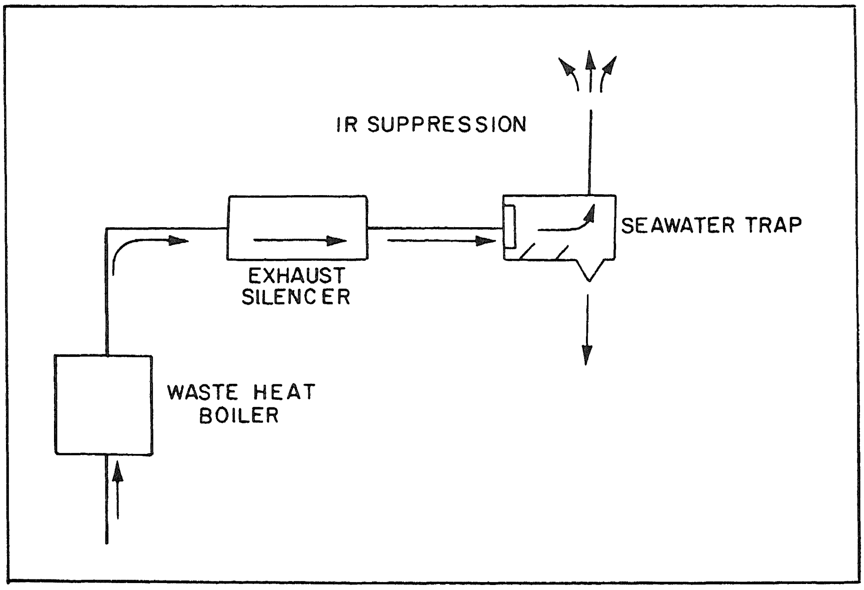

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Figure 8-40.—No. 3 exhaust configuration.

discharges from the port side on the 01 level aft.

SILENCERS.—The silencers have sound deadening material. They are encased in a perforated stainless steel sheet cylinder. This is suspended in the center of the exhaust duct. This unit with the duct wall insulation provides the required sound reduction to meet the airborne noise requirements.

IR SUPPRESSION.—The purpose of the IR suppression system is to reduce the exhaust gas temperature. This is done before it is discharged to the atmosphere. This minimizes heat sensing of the ship by other vessels and aircraft. The system has a manifold in the exhaust duct. Through this, seawater is sprayed into the exhaust gas stream. The spray manifolds for the No. 1 and No. 2 engines are located near the duct exits. The manifold for the No. 3 engine is located at the entrance to the green water trap. This system is not used on the Model 139; a BLISS cap is used on these sets.

GREEN WATER TRAP.—Because of the low location of the No. 3 engine exhaust duct exit relative to sea level, green water can enter the duct exit during high sea states. To stop the seawater flowing through the exhaust system, a tank is located in the duct near the exit (figure 8-40). Any water that enters the duct is trapped in the tank and drained overboard.

GTGS FIRE STOP AND CO_2 SYSTEM

The Allison 501-K17 is protected from damage if a module fire alarms. Two UV detectors are used to sense a fire condition in the engine enclosure. Only the engine enclosure is protected by the installed CO_2 system. The UV sensors and signal conditioners used on the GTGS are similar to the type used on the LM2500. The two sensors are mounted in the enclosure near the compressor inlet. The signal conditioners are mounted in the alarm terminal box located on the generator end of the base. The fire stop logic is controlled by the module cooling fan controller.

FIRE STOP LOGIC (MODEL 104)

When a fire is detected in the module of the Model 104 GTGS, a signal is sent to the fire shutdown relays.

The following actions then occur.

1. A 5-second delay occurs. This prevents any stray signals from causing a fire stop. The fire condition must exist for these 5 seconds.
2. After the 5-second delay, the following actions occur.

   a. Primary CO_2 is released.
   b. A stop command is sent to the LOCOP.
   c. The module fire damper is closed.
   d. The cooling fan is stopped.
   e. Ship's service LP air is ported to the 5th- and 10th-stage bleed air valves to keep them closed.
   f. Fire alarms are activated at the damage control console (DCC), EPCC, and the summary alarm at the switchboard.

3. The stop command to the LOCOP closes the fuel valve. When the GTGS rpm is below 12,780 rpm, the 14th-stage bleed air valve is closed.
4. Door interlocks are provided to prevent CO_2 discharge if the engine section module doors are open.

FIRE STOP LOGIC (MODEL 139)

The Model 139 fire stop is also controlled by the cooling fan controller. The fire stop sequence is different from that on the Model 104. The following actions occur if a fire is detected by the UV sensors.

1. The cooling fan(s) stop(s), if running.
2. A 20-second delay is activated. The fire signal must remain active during this 20 seconds.
3. After 20 seconds the following actions occur.

   a. A stop command is sent to the LOCOP.
   b. Ship's service LP air is ported to the 5th- and 10th-stage bleed air valves to keep them closed.
   c. The fire dampers are closed.

d. Primary CO_2 is released.

e. Fire alarms are activated at the DCC, EPCC, and the switchboard.

4. The LOCOP stop command closes the engine fuel valve. When the engine drops to 12,780 rpm, the 14th-stage bleed air valve closes.

CO_2 SYSTEM DESCRIPTION

The primary system has two 50-pound CO_2 cylinders (one master and one slave), two pressure switches, and two high-volume, low-velocity nozzles. The CO_2 cylinders are mounted in racks adjacent to the module. The pressure switches are located in the piping system. One is outside and the other is inside the enclosure. The nozzles are mounted on the air intake assembly.

Normally the primary bank is activated by fire stop logic. The primary bank can also be activated manually at the bank or remotely from the pull box. When the two pressure switches are operated by CO_2 pressure in the header, a CO_2 release alarm is activated locally and at the DCC. The summary alarm at the switchboard is also activated. Once released, CO_2 discharge cannot be stopped. The primary discharge is at the rate of 200 lb/min.

The secondary system has three 50-pound CO_2 cylinders (one master and two slave) and two high-volume, low-velocity nozzles. These are connected by a common piping system. The secondary bank must be released manually at the bank. The secondary system is not equipped with monitors or alarms. Once released, CO_2 discharge cannot be stopped. The secondary discharge is at the rate of 67 lb/min.

SUMMARY

In this chapter we have discussed the construction and operation of the Model 104 and Model 139 GTGSs used on the Allison 501-K17 engine. We have discussed the construction of the engine, its systems, and its control circuits. We have also discussed the reduction gear, generator, and support systems. After studying this material and completing the associated NRCC, you should be able to start qualifying as an operator of the Allison 501-K17. If your ship does not use these generators for electric power generation, you should know how GTs are used in constant speed applications.

Chapter 12 will also give you information to help you understand shipboard electrical equipment. GSE is rapidly becoming one of the major rates in the field of shipboard power generation and distribution. To become a competent EPCC operator, you must know not only the GTGS, but also the electric plant of the ship.

Remember, before you attempt to operate any ship's system, but especially one as important as a generator, follow all EOSS procedures. This will help prevent any major casualty from occurring because of operator error.

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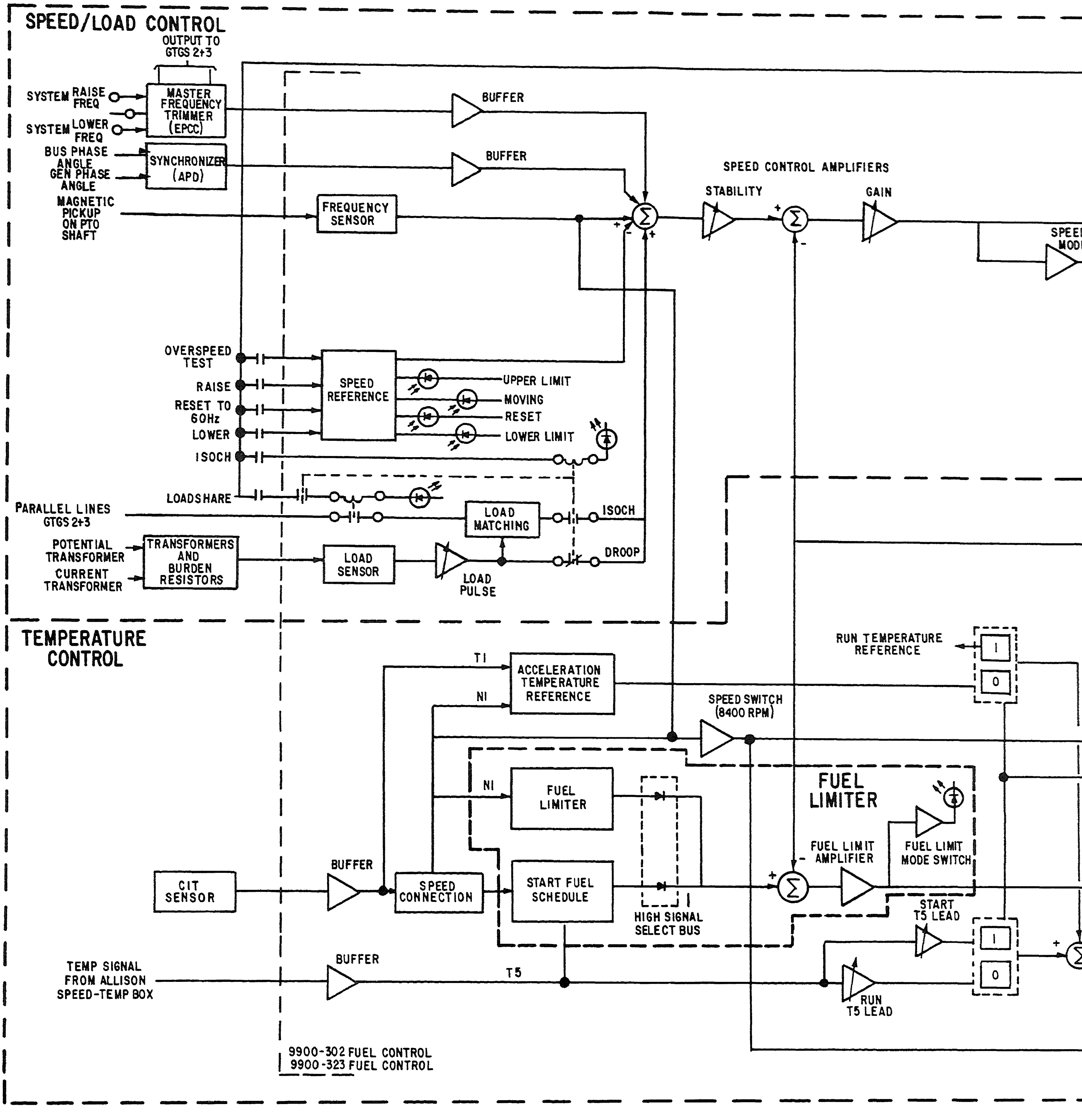
SPEED/LOAD CONTROL
OUTPUT TO GTGS 2+3
SYSTEM RAISE FREQ
SYSTEM LOWER FREQ
MASTER FREQUENCY TRIMMER (EPCC)
BUS PHASE ANGLE
GEN PHASE ANGLE
SYNCHRONIZER (APD)
BUFFER
BUFFER
MAGNETIC PICKUP ON PTO SHAFT
FREQUENCY SENSOR
SPEED CONTROL AMPLIFIERS
STABILITY
GAIN
OVERSPEED TEST
RAISE
RESET TO 60Hz
LOWER
ISOCH
SPEED REFERENCE
UPPER LIMIT
MOVING
RESET
LOWER LIMIT
LOADSHARE
PARALLEL LINES GTGS 2+3
LOAD MATCHING
ISOCH
DROOP
POTENTIAL TRANSFORMER
CURRENT TRANSFORMER
TRANSFORMERS AND BURDEN RESISTORS
LOAD SENSOR
LOAD PULSE
TEMPERATURE CONTROL
RUN TEMPERATURE REFERENCE
T1
N1
ACCELERATION TEMPERATURE REFERENCE
SPEED SWITCH (8400 RPM)
N1
FUEL LIMITER
FUEL LIMITER
FUEL LIMIT AMPLIFIER
FUEL LIMIT MODE SWITCH
BUFFER
CIT SENSOR
SPEED CONNECTION
START FUEL SCHEDULE
HIGH SIGNAL SELECT BUS
START T5 LEAD
TEMP SIGNAL FROM ALLISON SPEED-TEMP BOX
BUFFER
T5
RUN T5 LEAD
9900-302 FUEL CONTROL
9900-323 FUEL CONTROL

CHAPTER 9

ENGINEERING CONTROL SURVEILLANCE SYSTEM OPERATION (SPRUANCE CLASS)

Up to this point we have discussed operation, construction, and control of the gas turbine engineering plant from the local station. One of the revolutionary aspects of the gas turbine plant, though, is its ability to be operated from a central, remote location. This central point is known on all classes of gas turbine ships as the central control station (CCS). The CCS is the primary control watch station for operating nearly all major engineering equipment. Systems that are not controlled in the CCS may at least be monitored from there. This allows for reduced watch standing outside the CCS as opposed to older ships that required watch standers throughout the plant. Also, the EOOW and propulsion, electrical, and damage control watch standers have a quicker look at all vital parameters associated with plant operation.

Currently, two major designs exist for gas turbine CCSs; one for the *Perry* class frigates and one for *Spruance, Kidd*, and *Ticonderoga* classes. In this chapter we discuss the *Spruance* class CCS and point out the modifications made for the *Kidd* and *Ticonderoga* class CCSs. In the next chapter we will discuss the *Perry* class CCS.

The CCS is manned 24 hours a day either in port or at sea. At sea it is normally manned by an EOOW (either an officer or senior enlisted), a propulsion and auxiliary control console (PACC) operator (usually a senior GS petty officer), an EPCC operator (usually a petty officer GSE or EM), and a DCC operator (normally a Hull Technician). A fuel king will monitor the fuel system control console (FSCC) when necessary. Normally, inport watch in the CCS is stood by a single watch stander, who is usually a qualified engineering petty officer. At some point, you, as a GSE petty officer, will stand watch in the CCS. Also, GSEs maintain the control consoles in the CCS as one of their primary duties. Therefore, you should become familiar with all operations that may occur in the CCS.

After reading this chapter and completing the associated NRCC, you should have a good understanding of the function of the CCS. You should also know what operations each watch stander is responsible for and the control each has over these operations. We will also discuss some of the basic circuits involved in the consoles.

This material is meant for training purposes only. It is not meant to replace the EOSS or technical manuals.

With the help of an experienced GSE and by using the knowledge gained in this chapter, following the EOSS, and completing PQS requirements, you should have no problem qualifying in all aspects of CCS operations.

PROPULSION CONTROL

The PACC is a five-bay console (figure 9-1). The primary purpose of the PACC is to house the controls and status indicators of the four GTEs and all the auxiliary equipment for operating the main GTEs for both engine rooms. The operator, when seated facing the PACC panels, is facing the bow of the ship. All the controls and indicators on the two left bay panels correspond to the equipment in engine room No. 1 which drives the port shaft of the ship. All the controls and indicators on bay panels No. 3 and No. 4 are related to the equipment in engine room No. 2 which drives the starboard shaft of the ship. The controls and indicators on bay front panel No. 5 are directly related to the ship's

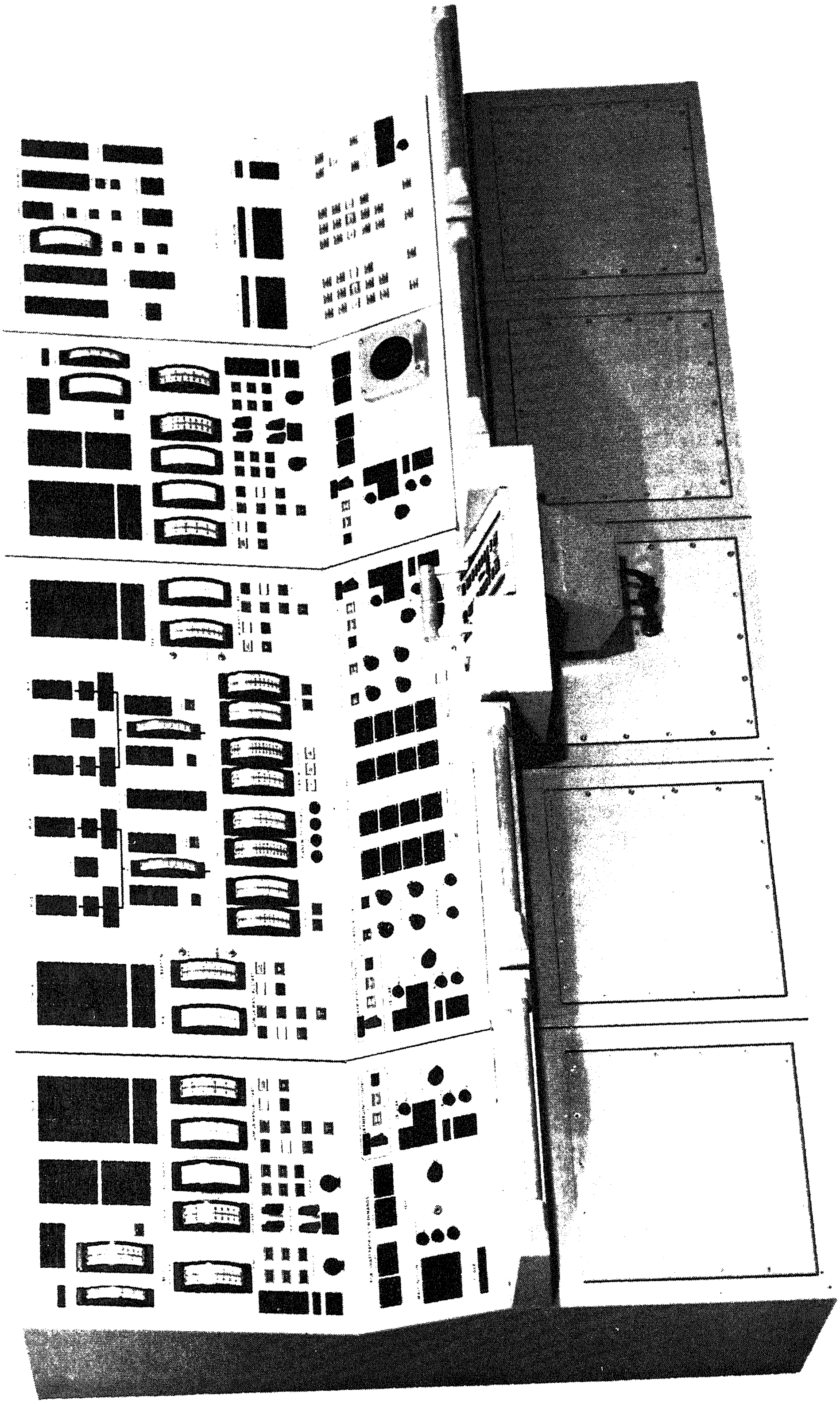

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Figure 9-1.—Propulsion auxiliary control console (PACC).

auxiliary subsystems and the GTM/GTG bleed air systems.

PACC FRONT PANELS

The following are descriptions of the eight front panels on the PACC.

● Panel A of figure 9-2 is the engine No. 2 panel and is divided into five major functions for engine room No. 1. A detailed view is shown in figure 9-3 (a foldout at the end of this chapter). By comparing these panels with those of the local console discussed in chapter 6, you will see the similarities; therefore, we will NOT discuss each indicator in this chapter. First on the panel: the RDCN GEAR LUBO section has an alarm indicator and a meter. Second: the CRP section has six alarm indicators, a meter, and a control switch. Third: the LUBE OIL system has two meters, six alarm indicators, three status indicators, six pump switch/status indicators, and a manual-automatic control switch. Fourth: the FUEL OIL system has 9 alarm indicators, 12 status indicators, 4 meters, 4 valve control switches, a manual-automatic control, 6 pump switch/status indicators, and 2 station-in-control status indicators. Fifth: the GTM 2B section has 30 alarm indicators, 9 status indicators, 4 meters, and the GTM 2B MANUAL START controls with 12 switch/status indicators.

● Panel B of figure 9-2 is the engine No. 2 demands panel and is divided into six sections. Figure 9-4 shows a detailed view. First, the thumbwheel controlled demand display (PORT SHAFT PROPULSION DEMANDS) of various conditions that exist within the propulsion system; second, the GTM 2B EMERGENCY CONTROLS; third, a MALFUNCTION section with ten alarm indicators (these alarm indicators inform the operator of malfunctions within the propulsion local control console (PLCC) or the PACC); fourth, the POWER display with an alarm and status lamp; fifth, the PACC TEST section for testing all the PACC alarm and status lamps and the siren, horn, and bell; sixth, the GTM 2B START/STOP section with a three-position start/stop mode selector switch, an initiate start pushbutton, eight start sequence status/alarm lights, a stop initiate pushbutton,

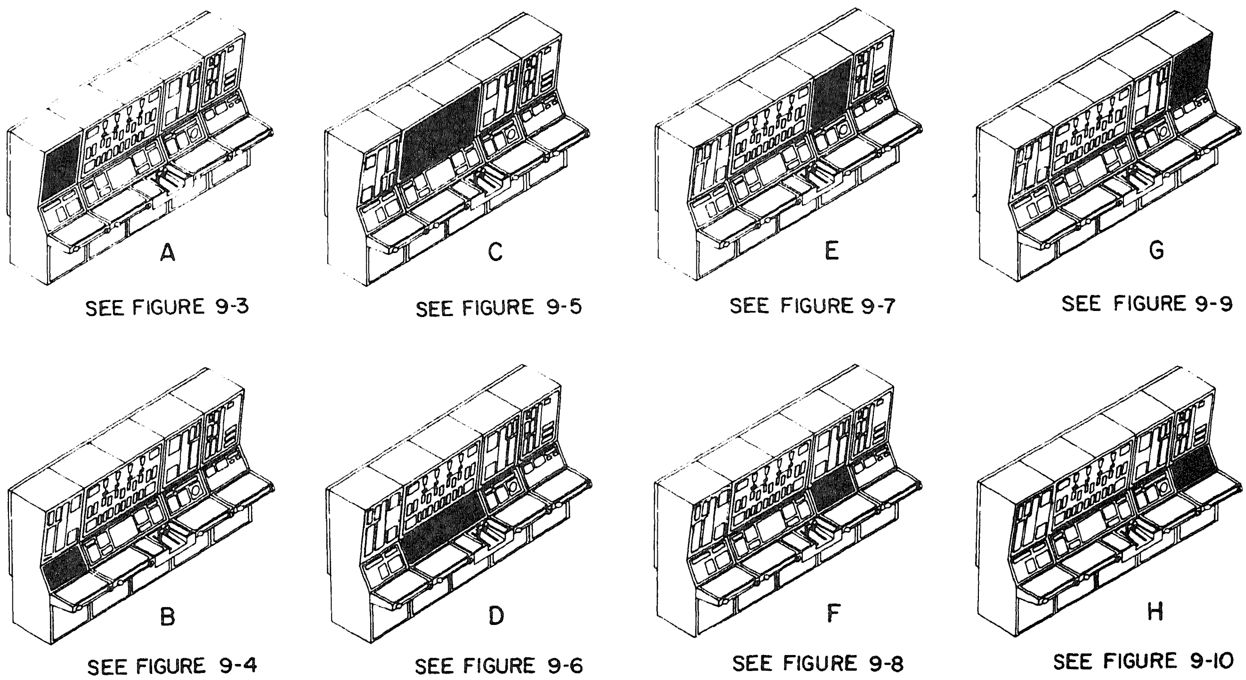

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Figure 9-2.—PACC—panel identification.

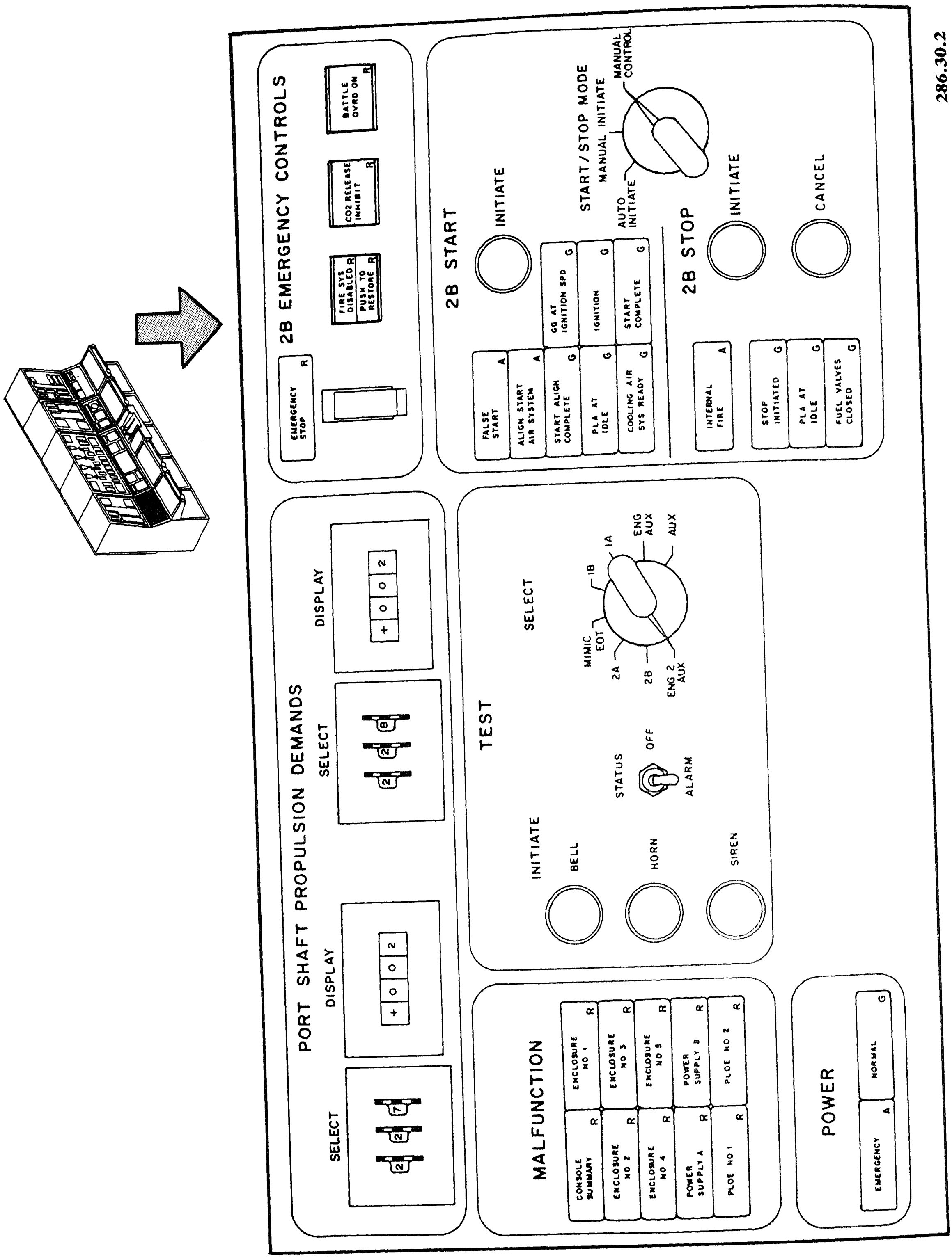

Figure 9-4.—PACC—engine No. 2 demands panel.

a cancel stop pushbutton, three stop sequence indicators, and an internal fire alarm indicator.

- Panel C of figure 9-2 is called the MIMIC panel because it provides a schematic representation of the four GTMs, clutches, reduction gears, and shafts. Figure 9-5 (a foldout at the end of this chapter) shows a detailed view. The left side of the MIMIC panel contains the alarm/status indicators and manual start switches/indicators for the GTM 2A, PLA and vibration meters, and vibration select switches for GTM 2A and 2B. The right side of the MIMIC panel is identical to the left but labeled for GTM 1A and 1B. The main center part of the MIMIC panel displays the status of each GTM, which station has control of the individual engine rooms, which engines are connected to the main shaft, the alarms and status indicators for the individual engines, and the automatic mode selectors (PLANT MODE SELECT, PLANT MODE CONTROL, ENGINE SELECT and mode change sequence indicators).

- Panel D in figure 9-2 is called the EOT panel. Its main function is concerned with EOT signals (RPM and PITCH signals) for both engine rooms. Figure 9-6 (a foldout at the end of this chapter) shows a detailed view. The extreme left and right portions of the panel have the GTM 2A and GTM 1B EMERGENCY CONTROLS and START/STOP sections. The START/STOP section has a start initiate pushbutton, eight start associated status lights, a stop initiate pushbutton, a cancel stop pushbutton, three stop sequence indicators, and an INTERNAL FIRE alarm indicator.

The EOT section of the EOT panel is divided into two subsections. The left half displays engine room No. 1 (port) RPM and PITCH signals. The right half displays engine room No. 2 (Stbd) RPM and PITCH signals. Both subsections have thumbwheel controls for rpm and pitch. It also has nine acknowledge pushbuttons for answering bell alert requests from the pilothouse.

The PORT MANUAL THROTTLE section contains a throttle auto/manual mode select switch, the manual throttle controls for both the GTM 2B and GTM 2A, a sea state control ON/OFF switch, a sea state adjust control, and a control for the port propeller pitch. The ALARM ACK section has two pushbuttons to acknowledge any PACC alarm or warning signal. The STBD MANUAL THROTTLE section has the same controls and indicators as the port manual control except they are for engine room No. 2, GTM 1B and GTM 1A. The THROTTLE TRANSFER section has pushbuttons for control/display of the station in control of the throttle.

- Panel E in figure 9-2 is divided into five major functions for engine room No. 2. Figure 9-7 (a foldout at the end of this chapter) shows a detailed view. The alarm displays, status displays, and controls for functions of engine room No. 2 (MRG, CRP, LUBE OIL, FUEL OIL, and GTM 1A) are identical to those discussed for the engine room No. 1 panel.

- Panel F in figure 9-2 is divided into four major functions. Figure 9-8 (a foldout at the end of this chapter) shows a detailed view. First, the 1A EMERGENCY CONTROLS and alarm displays for the GTM 1A; second, the thumbwheel controlled STBD SHAFT PROPULSION DEMANDS digital display of various conditions that exist within the control system; third, a SPEED CALIBRATION meter that displays the actual speed of the ship; fourth, the GTM 1A START/STOP section, and a matrix chart equating standard orders to knots (speed), shaft rpm, and pitch settings.

- Panel G in figure 9-2, the auxiliary and air panel, displays the status of various ships' subsystems. Figure 9-9 (a foldout at the end of this chapter) shows a detailed view. There are 11 status indicators for the IR suppression (IR SUPPR) system; 10 alarms for the ship's waste heat boiler (WASTE HT BLR) system; 2 meters and 3 valve controls for the STEAM system; 4 alarms and 3 pump control switches for the SEAWATER system; 5 alarm and 4 status indicators and 2 pump control switches for the FRESHWATER system; 7 alarms and 2 status indicators for the HP AIR system; 6 alarms and 2 status indicators for the ship's service (SS) AIR system; 3 alarms for the ship's air-conditioning (AIR COND) system; 4 alarms for the ship's DISTILLING system; 6 alarms for the ship's SEWAGE system; and 2 alarms for the ship's refrigeration (REFRD) system. In addition, the lower section has 18

alarms related to various air temperatures and pressures for each engine room (ENG ROOM 1 and ENG ROOM 2) and GTG 3.

- Panel H in figure 9-2 has switches and valve status indicators for the automatic and/or manual controls related to the bleed air system for each engine room. Figure 9-10 (a foldout at the end of this chapter) shows a detailed view. It also has the five control switches for prairie/masker air and valve status indicators for the GTG 3. In addition, it has a thumbwheel controlled demand digital display of various conditions that exist within the control system along with a print pushbutton for printing thumbwheel requested information.

THROTTLE CONTROL

Each of the GTs has its own individual main fuel control to which is attached a POWER LEVER actuator. This lever can be compared to the accelerator on an automobile. The power lever rotates in an arc from closed (13 degrees) to full open (about 113 degrees). All references to the position of the power lever are given in percentages that correspond to the PLA. As the PLA is increased, the GT rpm and the resultant ship's propeller shaft rpm are increased.

The speed of the ship is a function not only of the rpm of the propeller shaft, but also is directly related to the pitch angle of the ship's variable pitch propeller. Therefore, any discussion concerning the control of the ship's speed must include both the PLA and the propeller pitch even though they are separate systems.

The PLA actuator is physically located on the GTE. The electrical signal to this actuator is generated in the PLCC and FSEE and is referred to as the PLA command.

The propeller pitch actuator is physically attached to the oil distribution box mounted on the MRG in each engine room. The electrical signal to this actuator is generated in the PLCC and pitch electronics and is referred to as the PITCH command.

There are two methods of providing PLA and pitch commands to the gas turbines. The first is manual throttles (from either the PACC or PLCC) and the second is the integrated throttle control (ITC) from either the PACC or the SCC. There are two methods of communicating desired speed settings from the SCC to the PACC/PLCC. The first is through the standard order EOT and the second is through the digitized EOT.

Manual Throttle/Pitch Control

With control at the PLCC, PLA/PITCH settings are accomplished by positioning the throttle/pitch levers. There is one throttle lever for each GTM with a latching device for operating both levers simultaneously. There is one pitch lever for control of pitch. With control at the PACC, the PLA/PITCH settings are accomplished using rotary potentiometers on the EOT panel. There is one potentiometer for each GTM and one for pitch. Use of manual throttles at PACC bypasses PACC auto throttle circuitry.

Integrated Throttle Control

Integrated throttle control (ITC), or automatic throttle control, is available at the PACC (figure 9-11) or at the SCC. There are two levers, one for each shaft, for simultaneous control of the GTMs and controllable reversible propeller (CRP). These levers can be mechanically latched together to control both shafts simultaneously or unlatched for individual shaft control (figures 9-12 and 9-13).

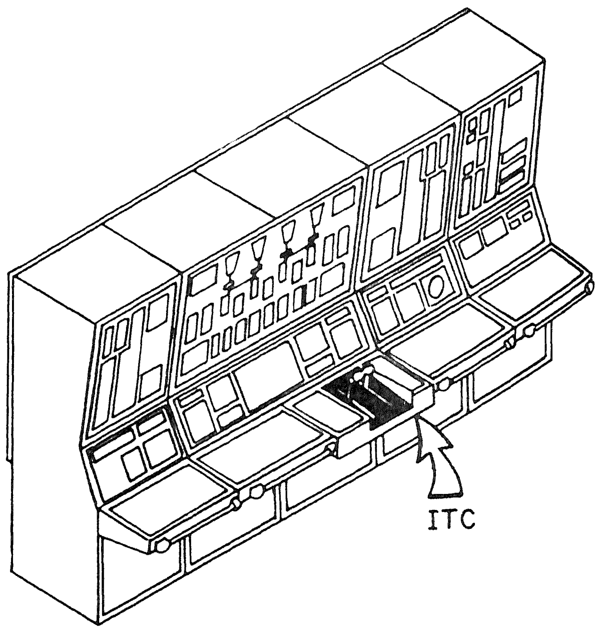

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Figure 9-11.—PACC—ITC location.

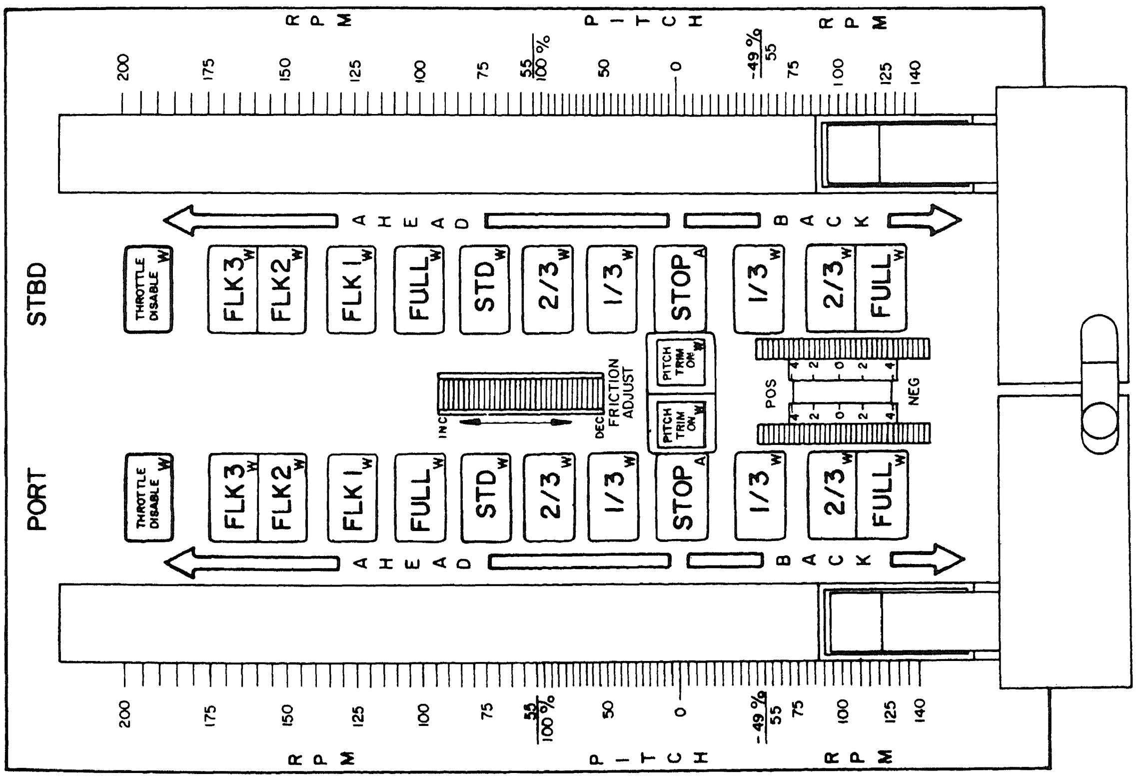

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Figure 9-12.—PACC—ITC.

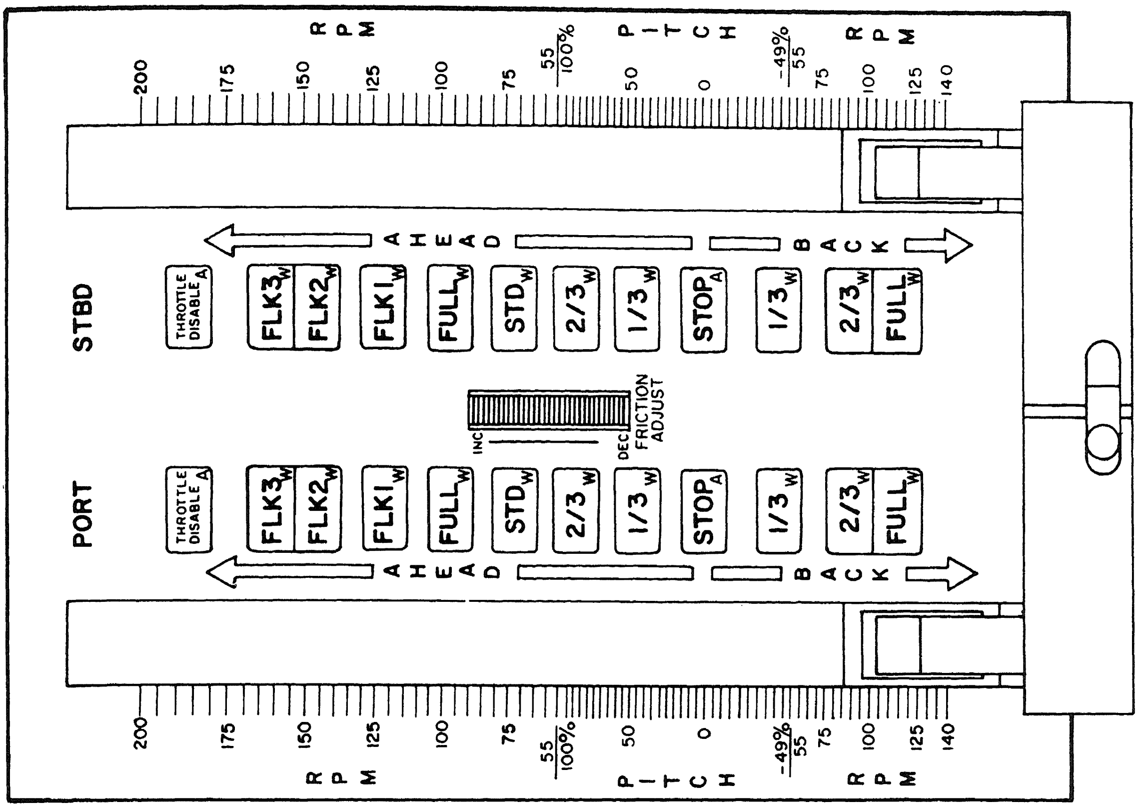

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Figure 9-13.—Ship control console—ITC.

NOTE: The major difference between the two ITCs is that the PACC ITC has provisions for pitch trim, while the SCC ITC does not. Therefore, the two ITCs are not interchangeable. This system is called ITC because the information for both pitch and rpm for an engine room is given by one analog reference voltage. Two references, one for each shaft, are generated by each of the levers at the console (PACC or SCC) that has control.

Table 9-1 shows the rpm and pitch relationship over the range of the throttle lever. In the ahead direction, shaft rpm is held at 55 until propeller pitch reaches 100 percent. After this point, shaft rpm is increased and pitch remains at 100 percent. In the astern direction, shaft rpm is held at 55 until propeller pitch reaches −49 percent. After this point, shaft rpm is increased and pitch remains at −49 percent.

Figure 9-14 is a functional block diagram of the ITC which provides the rpm and pitch integration. The analog reference voltage developed by the ITC levers at the PACC or the SCC is given to three schedulers and one compensation circuit. These are the PLA scheduler, the rpm scheduler, the rpm compensation, and the pitch scheduler.

The PLA scheduler develops an analog voltage proportional to ITC lever position. This scheduler provides a feed forward reference command to the PLA. The reference command gives an approximate position of the PLA on the engine for an rpm setting on the ITC. This schedule is changed depending upon split or full power (one engine or both engines) operation. In split plant operation, the maximum allowed PLA command is 140 rpm. In full power operation, the rpm is allowed to go above 140 rpm. This signal is then delivered to a rate limiting circuit which allows smooth on- and off-line transfers of engines. This is done by preventing PLA command reference from rapidly changing, thus minimizing GTM surging.

The rpm scheduler works with the PLA scheduler to control shaft rpm. The rpm scheduler develops an analog voltage proportional to ITC lever position. The voltage represents the rpm called for by the ITC lever setting. It is compared with a voltage that represents actual shaft rpm from the shaft tachometer. They are algebraically summed and an error voltage is developed whose magnitude and polarity are related to the error between the commanded and actual rpm. This signal is then passed to the rpm compensation circuit (discussed later). There it is added to or subtracted from the PLA signal to control shaft rpm accurately. The corrected PLA signal command voltage is then sent to the circuitry at

Table 9-1.—ITC—RPM-Pitch Relationship

ITC TRAVEL	SHAFT RPM	PROPELLER % PITCH
	200	100
	175	
	150	
AHEAD	120	
	100	
	75	
	55	100
		75
		50
		25
STOP	55	0
		-25
	55	-49
ASTERN		
	75	
	100	
	125	
	140	-49

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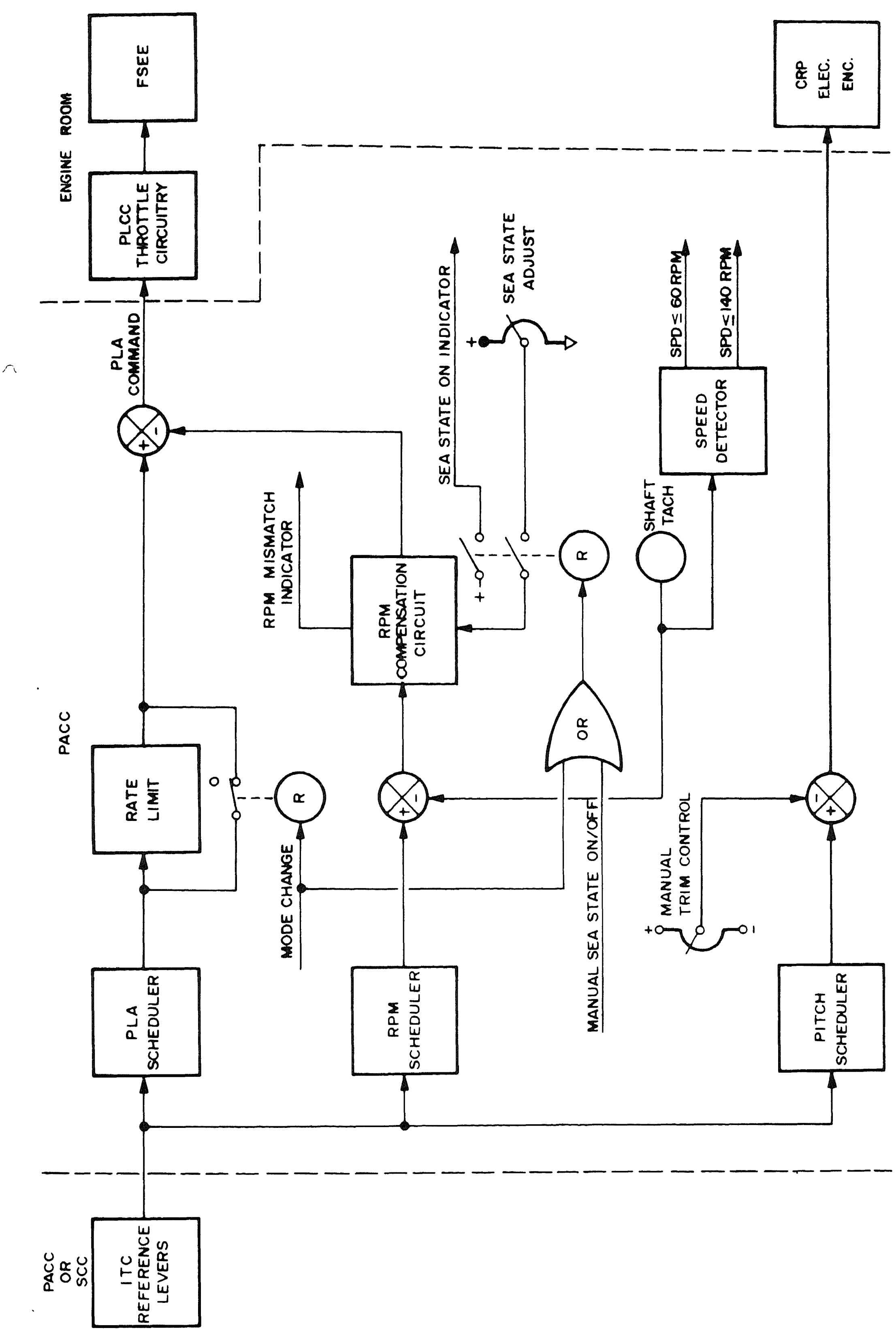

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Figure 9-14.—Functional block diagram of the ITC circuit.

the PLCC and then to the FSEE. Figure 9-15 shows the relative PLA command output for a given ITC lever position.

The rpm compensation circuitry provides for sea state adjustment. A manually operated sea state adjustment is provided with the ITC circuitry at the PACC only. This control allows reduction of the ITC sensitivity to shaft rpm fluctuations caused by sea state conditions. It can decrease the ITC system relative gain from 1.0 down to 0.1. At a setting of 1.0, or sea state off, the ITC will regulate shaft rpm to within a 12-rpm error. As the sea state control is adjusted to lower gain values, the ITC will regulate, but within greater rpm errors. This control is automatically disabled during engine transfer (on-line or off-line) to allow for minimum transfer times. A pushbutton switch/indicator is provided at the PACC for each shaft to indicate SEA STATE ADJUST ON (figure 9-6). An output from the compensation circuit COMMAND RPM MISMATCH is provided to an alarm indicator at the PACC when an error signal of 5 rpm or greater between the command and tachometer persists for more than 1 minute.

The shaft tachometer signal is also used to detect discrete rpm levels. A shaft speed less than or equal to 60-rpm signal is used in the throttle enable and shaft brake logic circuitry. A shaft speed less than or equal to 140-rpm signal is used in the plant mode transfer logic.

The pitch scheduler, shown in figure 9-14, provides a reference voltage to the CRP electronics enclosure. A manually operated pitch trim adjustment for each shaft is provided at the PACC ITC only, although it may be used by the PACC operator when the SCC is in control. The trim control has a range of ±10 percent of the existing pitch over the range of pitch schedule output. A detent is provided at the 0% pitch trim position for ease of operator usage. A PITCH TRIM ON indicator light is provided for each shaft at the PACC (figure 9-12). This indicator is illuminated when the pitch trim control is moved off the 0-percent setting. Figure 9-15 shows the relative pitch command output from a given ITC lever position with the trim adjustment limits.

A COMMAND PITCH MISMATCH alarm indicator is provided at the MIMIC panel of the PACC (figure 9-5). It provides an alarm if the

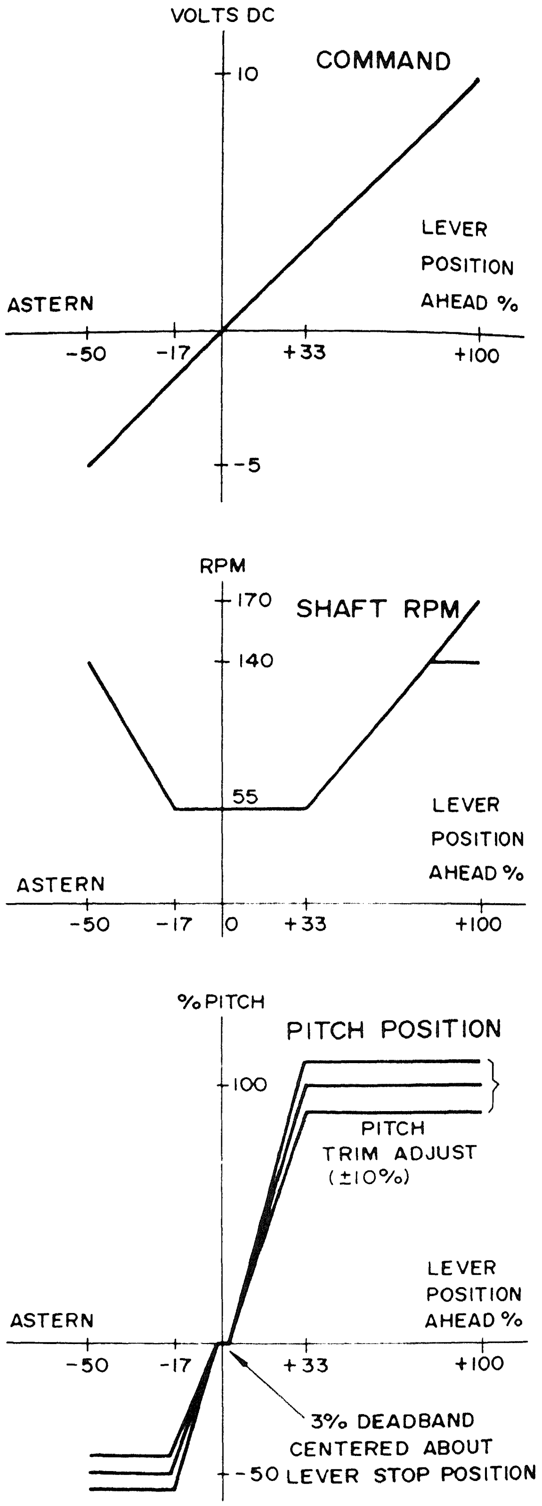

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Figure 9-15.—Relative PLA command output for ITC lever positions.

commanded pitch signal and actual pitch signal disagree by a 5-percent error for 3 minutes.

Throttle Control Transfer

Throttle/pitch control is possible at one of three locations. For the SCC to have integrated throttle control, both the PLCC and PACC must have their remote stations selected. That is, the PLCC must have at least one GTM and EOT control transferred to the PACC. The PACC must have the throttle control transferred to the SCC. See figure 9-16 for the relationship between consoles. At the PLCC only manual throttle and pitch control for their respective GTMs is available. Manual control of an individual GTM may be transferred to the PACC from the PLCC. At the PACC each GTM may be controlled manually by rotary potentiometer controls which operate the same as the lever controls found at the PLCC. Either or both GTMs may then be placed in auto (ITC) control. To transfer throttle control from the PACC to the SCC, both GTMs must be in auto throttle control. The PACC may take throttle control from the SCC at any time. The PLCC may take throttle/pitch control from the SCC or PACC at any time.

Standard Orders

Standard orders originate at the SCC and are used when the PACC has control of the throttles. The SCC operator moves the ITC to the new position and then depresses a STD ORDER ALERT pushbutton. This signal is routed to the PACC and PLCC. At the PACC on the integrated throttle unit (figure 9-12), the new standard order light begins flashing and an audible alarm is sounded. When in automatic mode, the PACC operator responds to the

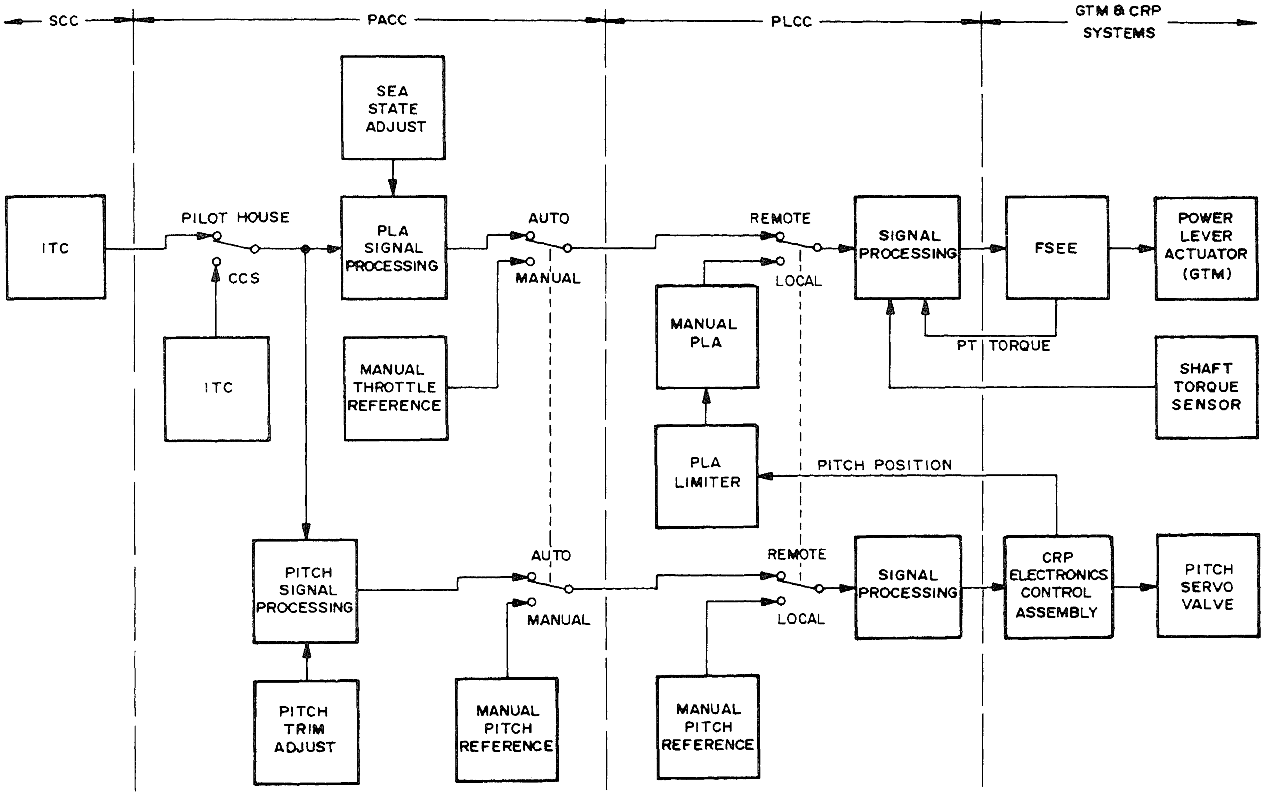

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Figure 9-16.—Throttle and pitch control block diagram.

flashing light by moving the ITC lever to the new position. Then the STD ORDER ACKNOWLEDGE pushbutton (figure 9-6) is depressed. The ACKNOWLEDGE signal causes the flashing light to go to a steady state. The signal generated by the PACC ITC lever movement is processed through the same circuitry that the SCC/ITC signal used. The PACC manual mode of responding to standard orders is slightly different. The SCC operator generates a new standard order by moving the ITC. This signal generates an alarm and a flashing light on the PACC ITC. The PACC operator acknowledges the alarm by depressing the STD ORDER ACKNOWLEDGE pushbutton. Then the operator manually adjusts the two PLA potentiometers and the PITCH potentiometer (figure 9-6) associated with each engine room. The signals from the potentiometers are then routed via hardwire to the PLCC. There they are processed before going to the PLA and PITCH actuators.

Engine Order Telegraph

The EOT system is a digital system used primarily as a backup throttle communications system (figure 9-6). The signals used are (1) RPM ALERT, (2) PITCH ALERT, (3) RPM digital thumbwheel setting, (4) PITCH DIGITAL thumbwheel setting, (5) RPM ALERT ACKNOWLEDGE, (6) PITCH ALERT ACKNOWLEDGE, (7) ship's shaft actual RPM, and (8) propeller actual PITCH. This system is used when the PACC or PLCC is in control of the throttle.

The actual RPM and PITCH are digitally displayed at the SCC, PACC, and PLCC. When the OOD orders the SCC operator to change RPM and/or PITCH, the following events occur. The SCC operator sets the new values of RPM and PITCH on the thumbwheels and then depresses the RPM and PITCH ALERT pushbuttons. These signals are sent to the PACC and PLCC where they appear on the digital displays labeled RPM and PITCH ORDERED. At the same time an audible alarm is sounded and the RPM and/or PITCH ACKNOWLEDGE pushbutton lights begin to flash. When the PACC is in control of the throttle, the operator responds in the following manner. (See figure 9-6.) The operator sets the new RPM and/or PITCH on the thumbwheels and depresses the flashing RPM and/or PITCH ACKNOWLEDGE pushbutton. The light stops flashing and the audible alarm is turned off. The operator then manually changes the proper PLA and/or PITCH potentiometer or moves the ITC lever.

The signals from the potentiometer are sent via hardwire to the PLCC and are then sent to the PLA and/or PITCH actuator. As the shaft RPM and PITCH change, they are fed back into each console as ACTUAL RPM and ACTUAL PITCH values.

GAS TURBINE MODULE CONTROL AND MONITORING

Each GTM has three possible start/stop modes that are operator selectable. The three start/stop modes are MANUAL, MANUAL INITIATE, and AUTO INITIATE (plant mode). Auto initiate is available only at the PACC.

MANUAL CONTROL MODE

The manual control mode calls for the operator to generate the start or stop commands at each and every step of the sequence at the appropriate times. Sequencing of these manual controls is the same as the time sequential flow charts provided for manual initiate start/stop. Manual start/stop control is available at the PLCC or PACC. It is discussed in detail in chapter 6 of this manual. (See figures 9-3, 9-5, and 9-7 for the manual control pushbuttons on the PACC.)

MANUAL INITIATE MODE

Manual initiate mode consists of starting and stopping the GTM in a semiautomatic mode. In this mode, the engine will start or shut down automatically. That is, the control electronics at the PLCC will automatically sequence the start or shutdown steps required. This mode is semiautomatic because the clutch and brake operation to couple the GTM to the MRG must be done manually. Manual initiate mode is available at either the PLCC or PACC.

As discussed in chapter 6, the operator must be aware of the condition of the plant before initiating a start. If one engine on a shaft is already on line and the clutch is engaged, no action is required by the operator except to initiate the start. If the shaft is static, no engine is on line and the shaft is not turning. Then the operator must first engage the clutch on the engine to be started. This procedure is unique to DD-963/DDG-993 class ships and is referred to as static (dead) shaft pickup. Static shaft pickup can be used with manual control mode and manual initiate mode. However, it is not used for plant mode as there is no plant mode for secure to split plant or full power.

We will not discuss the engine start sequence in the manual or manual initiate mode in this chapter. These sequences were covered in detail in chapter 6.

PLANT MODE (AUTOMATIC)

Plant mode control electronics is located at the PACC. A layout of pushbuttons and indicators for plant mode change is shown in figure 9-5. The control works with the start/stop logic at the PLCC. In plant mode control, the operator can start or shut down main engines in both engine rooms without using the individual GTM start/stop controls. The plant mode control is used when all the following systems are aligned as indicated below.

- GTM START/STOP MODE in AUTO INITIATE
- THROTTLE CONT in AUTO
- Clutch/Brake in AUTO BRAKE CLUTCH MODE
- Air CONTROL MODE in AUTO

With the above systems in auto and the propulsion plant in one of three propulsion configurations (secure, split plant, full power), plant mode control is enabled. Secure plant mode is defined as no GTMs driving either propeller shaft. Split plant mode is defined as one GTM per engine room driving a shaft. Full power mode is defined as both engines per engine room driving a shaft. With plant mode control enabled, the following mode changes can be performed.

- Split plant to full power (figure 9-17)
- Full power to split plant (figure 9-18)
- Full power or split plant to secure (figure 9-19)
- Change engine (split plant to split plant)

NOTE: Secure to split plant is not available except on CG-47 class ships.

The following status indicators are found on the PACC MIMIC panel (figure 9-5).

1. OUT OF SERVICE—the key switch at the PLCC is in the out of service position. This prevents starting of the GTMs.
2. SECURED—the auxiliary systems are not running or are not ready. These systems are fuel oil, lube oil, MRG, and bleed air.
3. STANDBY—the auxiliary systems are ready. The systems and conditions required are
   a. fuel oil—header pressure greater than 40 psig,
   b. lube oil—header pressure greater than 9 psig,
   c. MRG—turning gear disengaged, and
   d. bleed air—header pressure greater than 40 psig.
4. RUNNING—the GTM has N_{GG} greater than 4300 rpm, $T_{5.4}$ greater than 400°F, and clutch disengaged.
5. ON LINE—the engine is running and the clutch is engaged.

Split Plant to Full Power

Figure 9-17 (a foldout at the end of this chapter) shows the sequence of events when plant mode control is used to place the two standby GTMs on line with the two GTMs already on line. The AND logic at the top center of the flow chart shows the five conditions needed to begin a request for full power from a split plant mode. These five conditions are as follows.

1. GTM start/stop mode is in AUTO INITIATE.
2. Throttle control is in AUTO.
3. SPLIT PLANT mode is shown.
4. Start mode change is commanded.
5. FULL POWER mode is selected.

When these conditions are satisfied, the MODE CHANGE STARTED indicator (figure 9-5) is illuminated and a signal is sent to the throttle control circuitry. Control now enables the four AND logic blocks and automatically selects the two GTMs in standby mode to be started. If either engine is SECURED or OUT OF SERVICE, the mode change logic will be automatically reset and the mode change will be terminated. After both engines are selected, the ENGINE SELECT pushbutton switch/indicator for each will be illuminated at the PACC. Control now flows through both OR logic blocks to the AND logic located at the flow chart center. The AND logic is satisfied and control issues start commands to start circuitry at each PLCC for the selected GTMs. Control now waits for both engines to reach running state. If a false start is detected, the plant mode control will display the RESTART or SELECT ALTN (alternate) indicator and sound an audible alarm. The control then enters a 20-second delay. This allows the operator time to activate the ENGINE RESTART pushbutton and try to restart the same engine again. If the 20 seconds elapses, the MODE CHANGE RESET indicator will be illuminated. Then the operator must manually reset the control with the PLANT MODE CONTROL RESET pushbutton. After receiving RUNNING signals for both GTMs, control will issue commands and illuminate indicators as follows.

1. Engage clutch command
2. Release brake command
3. ENGAGE CLUTCH display
4. RELEASE BRAKE display
5. FULL POWER mode display
6. GTMs RUNNING display

Control now waits for signals from MRG control indicating that the clutches are engaged. At this point, the GTM ON-LINE indicators are illuminated. The plant mode control then enters a 45-second time delay to allow time for the GTM throttle to stabilize. After the 45 seconds has elapsed, the MODE CHANGE COMPLETE indicator will be illuminated for 15 seconds. Then the plant mode logic is automatically reset.

Full Power to Split Plant

This mode change allows the operator to select one GTM in each engine room to remain on line. The nonselected GTM clutches are automatically disengaged and the GTM status indicates RUNNING. The flow chart on figure 9-18 (a foldout at the end of this chapter) shows the sequence of events that takes place when changing modes from full power to split plant. The AND logic at the top center shows the five conditions needed to begin the mode change. These five conditions are as follows.

1. GTM start/stop mode is in AUTO INITIATE.
2. Throttle control is in AUTO.
3. FULL POWER mode is shown.
4. Start mode change is commanded.
5. SPLIT PLANT mode is selected.

When these five conditions are satisfied, the MODE CHANGE STARTED and SELECT ENGINE indicators are illuminated. A signal is also sent to the throttle control circuitry in both shaft card cage assemblies in the PACC (figure 9-19). This signal disables the RPM/PLA rate limit electronics. This allows minimum engine transfer time. The SEA STATE ADJUST is enabled after the mode change is completed. Control now enables the operator to select one GTM to remain on line in each engine room. The flow chart shows the three conditions needed at each AND logic to select engines. These three conditions are as follows.

1. Plant mode control START MODE CHANGE is started.
2. Engine ON LINE is shown.
3. Engine select command is started.

When the conditions are met, an ENGINE SELECT display shows which engines have been selected. Control now flows through both OR logics to the AND logic located at the flow chart center. The following four conditions are needed before continuing.

1. One GTM selected in engine room No. 1
2. One GTM selected in engine room No. 2
3. Shaft No. 1 rpm less than 140
4. Shaft No. 2 rpm less than 140

Because of the power limits in the split plant mode, shaft rpm of 140 or more cannot be requested. When the four conditions are satisfied,

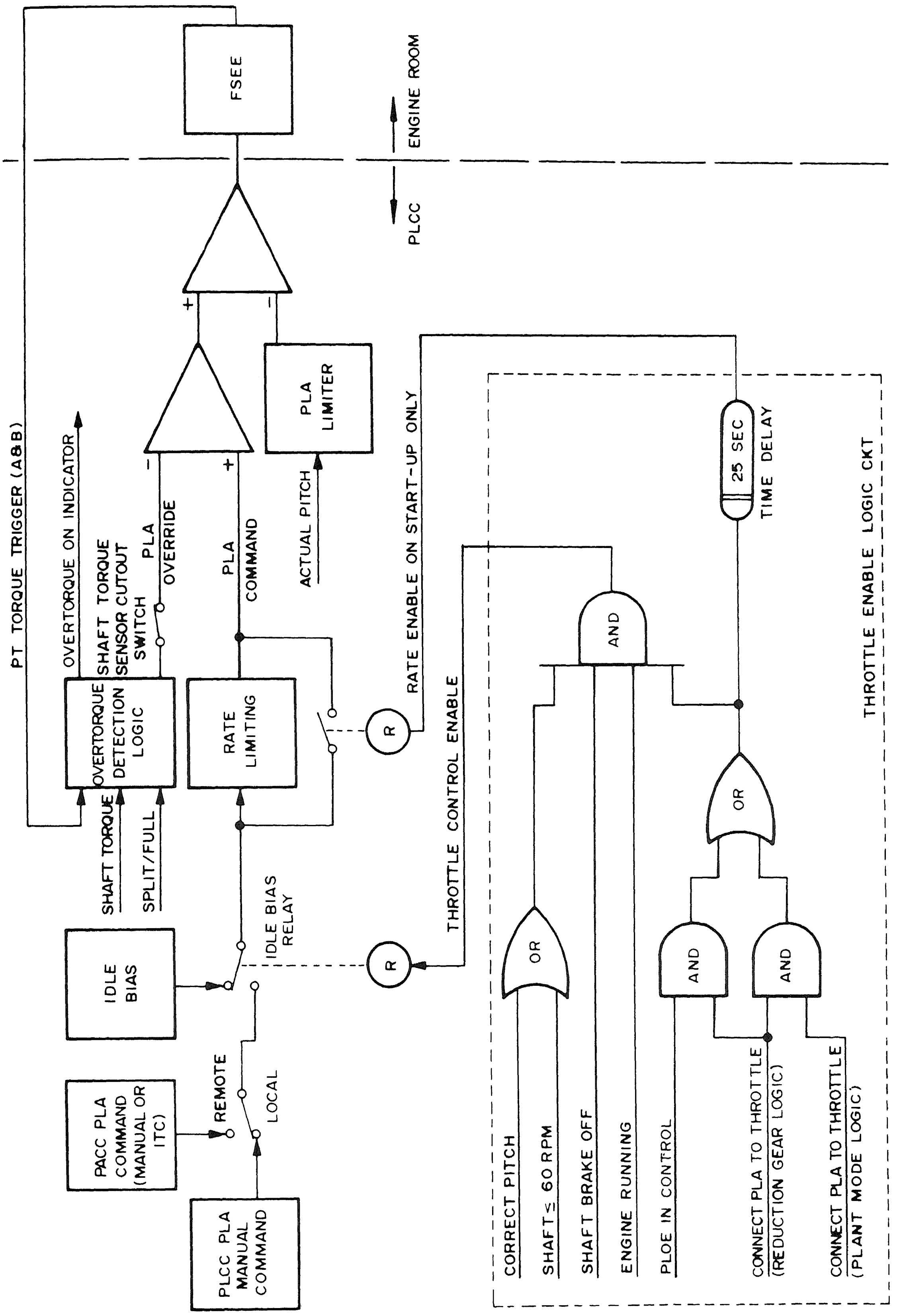

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Figure 9-19.—PLA processing.

two commands are sent to each PLCC. First, the throttle control for each nonselected GTM is commanded to connect PLA to idle. At the same time, the change mode control will illuminate the PLA AT IDLE indicator at the PACC. Second, a stop command is sent to the stop sequencer. The stop control will begin the same stop sequence as for the stop command issued in the manual initiate mode. The plant mode change control now waits for GTM control at each PLCC to signal that engines are at idle speed. Control then issues a command to disengage clutches and illuminates the DISENGAGE CLUTCH indicator at the PACC. After both MRG control circuits have shown that the clutches are disengaged, the following actions are begun.

1. The 45-second timer is started.
2. SPLIT PLANT display is illuminated.
3. GTM RUNNING is displayed for non-selected engines.

Control then delays for 45 seconds to allow time for the GTM throttles to stabilize. After the 45 seconds has elapsed, the MODE CHANGE COMPLETE indicator is illuminated for 15 seconds. Then the plant mode logic is reset. The stop sequencer begins a 5-minute idle speed cooldown period for the engines. After the 5 minutes has elapsed, the engines will be secured, the brake will be engaged, and the GTM SECURED indicator at the PACC is illuminated.

Full Power or Split Plant to Secure

This plant mode change is similar to the full power to split plant mode change just discussed. The flow chart in figure 9-20 (a foldout at the end of this chapter) shows the sequence of events that takes place when changing to the secure plant mode. The AND logic at the top center shows the five conditions needed to begin the mode change. These five conditions are as follows.

1. GTM start/stop mode is in AUTO INITIATE.
2. Throttle control is in AUTO.
3. FULL POWER or SPLIT PLANT mode is shown.
4. Start mode change is commanded.
5. SECURE mode is selected.

When these conditions are satisfied, two commands are issued to each GTM: connect PLA to idle and stop engines. Also, the MODE CHANGE STARTED and PLA AT IDLE indicators are illuminated. Control then waits for all engines to reach idle speed. At this point, the clutch disengage command is sent to all MRG control circuits. After the clutches are disengaged, the following actions are begun.

1. The 45-second timer is started.
2. SECURE plant mode display is illuminated.
3. GTM RUNNING indicator lights are illuminated.

Control enters a 45-second delay and will continue from this point in the same manner as discussed in the last topic.

Change Engines

The change engines command allows for GTMs in the same engine room to be rotated on and off line automatically when in the split plant mode. The change engine mode begins when a split plant exists and the START MODE CHANGE and CHANGE ENGINE pushbuttons are depressed simultaneously. Control will then request the operator to select the engine or engines to be placed on line. The operator may now select to rotate engines in one or both engine rooms. After one engine is selected, a 10-second delay is entered. This allows time for the operator to select a second engine if desired. After the 10 seconds has elapsed, control will enter the same mode change sequence as the split plant to full power change. After the engine or engines are placed on line, a 30-second delay is entered. This allows time for any transfer disturbance to settle out. After this delay, the engine or engines to be rotated off line enter the same mode change sequence as the full power to split plant change.

During any of the mode change sequences discussed, if a brake release command is issued by the plant mode logic to a GTM that is running and the brake is not released within 20 minutes, the RELEASE BRAKES indicator flashes and an audible alarm is sounded.

ELECTRIC PLANT CONTROL CONSOLE

The EPCC (figure 9-21) provides the console operator with automatic control logic and

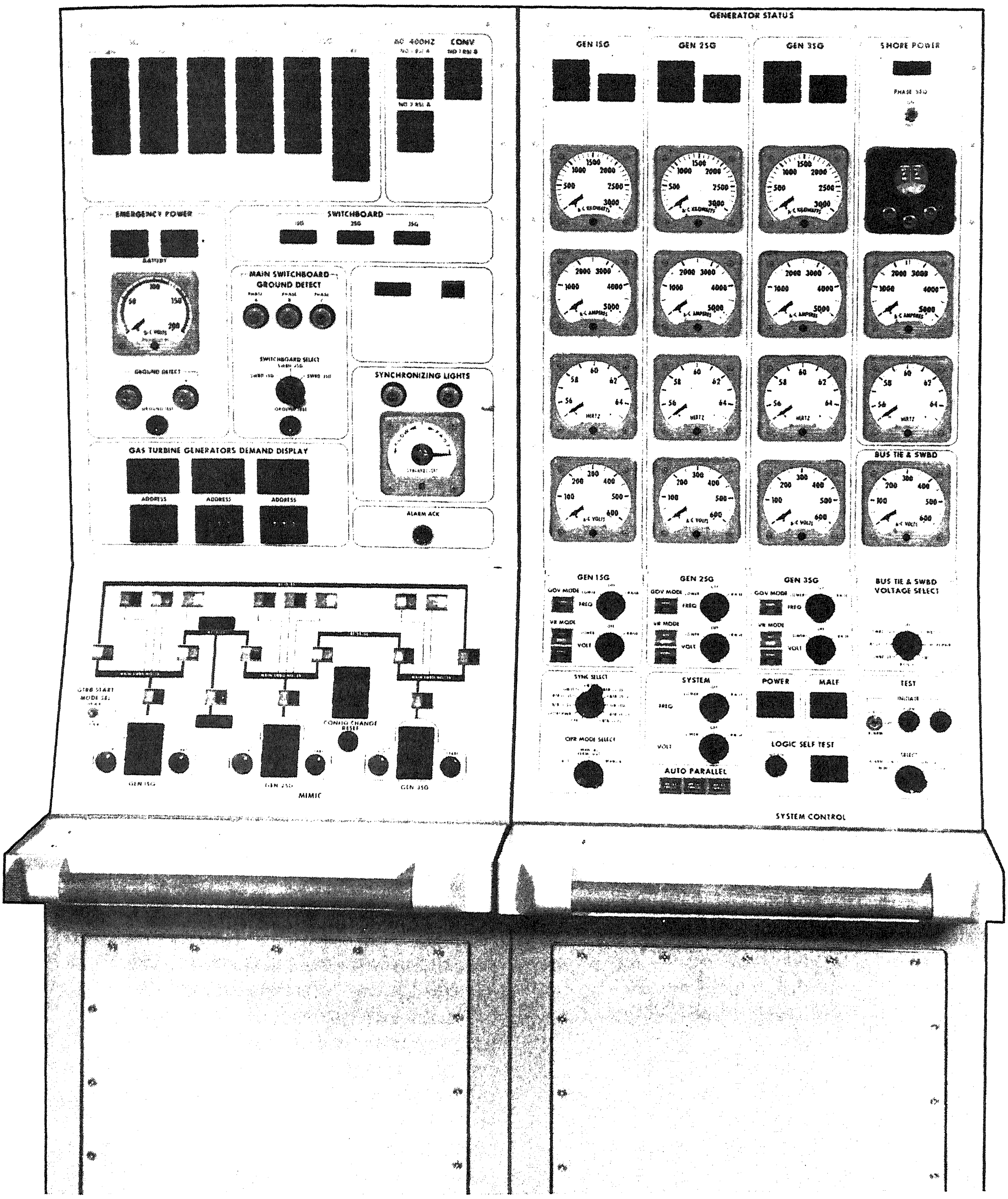

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Figure 9-21.—Electric plant control console.

electric plant status and performance monitoring displays. The EPCC also contains manual control for operating the ship's electric power generating and distribution system. Thus, the EPCC operator can start and stop any GTG, raise and lower voltage and frequency, open and close generator breakers (GBs) and bus tie breakers (BTBs), and monitor the entire electric plant operation at the EPCC. The EPCC displays and controls are located on four front panels (figure 9-22): the MIMIC and distribution control panel, the system control panel, the generator status panel, and the alarm/status panel. Each panel is discussed in the following paragraphs.

MIMIC AND DISTRIBUTION CONTROL PANEL

The MIMIC panel (figure 9-23, a foldout at the end of this chapter) contains a line diagram depicting the ship's electric plant configuration. Appropriate displays and controls are located according to function. Split legend pushbutton switch/indicators combine the functions of starting circuit breaker (CB) close and trip commands and provide the corresponding status displays. Pertinent generator controls and indicators are also located on the MIMIC panel.

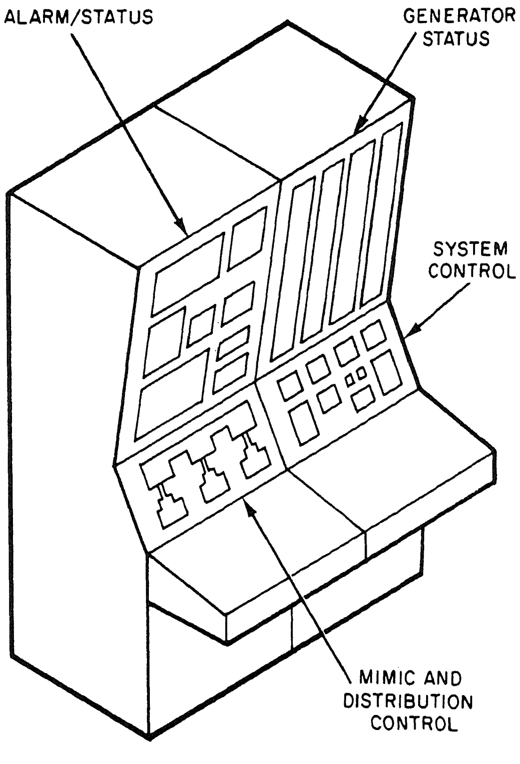

Figure 9-22.—EPCC—panel identification.

SYSTEM CONTROL PANEL

The system control panel (figure 9-24, a foldout at the end of this chapter) contains the controls and indicators for the voltages and frequencies of the three generators, governor and voltage regulator mode control and indicators, console mode control, SYNC (synchronizing) select, system frequencies and voltage control, self-test, power malfunction, and auto paralleling command switches/indicators.

GENERATOR STATUS PANEL

The generator status panel (figure 9-25, a foldout at the end of this chapter) continuously monitors alarm displays for each of the three generators and meters for various parameters of ship's power and shore power. The meters and displays are arranged in separate columns under the headings of power, current, frequency, and voltage for each generator and for shore power. This arrangement allows the operator to simultaneously monitor a particular output of all the power sources.

ALARM/STATUS PANEL

The alarm/status panel (figure 9-26, a foldout at the end of this chapter) contains the following displays and alarms: (1) demand displays, (2) generator and GT status and alarm indicators, (3) 400-Hz converter status and alarm displays, (4) main switchboard status displays, (5) emergency power status and alarm displays, (6) a battery voltage meter, (7) ground test controls, (8) switchboard and UPS indicators, (9) load shedding control and indicator, (10) synchroscope, (11) synchronizing lights, and (12) alarm acknowledge control.

OPERATIONAL CONTROLS

Electric plant remote manual and automatic operating control, metering, and configuration

status indicating components are located in the CCS at the EPCC. In normal operation the EPCC has complete remote control and monitoring capability of the electric plant. This capability includes the automatic, manual permissive, and manual CB control; automatic and manual generator set start and stop control; and voltage and frequency adjusting control.

A GTG control panel (LOCOP) (mounted on the side of each GTGS) provides the logic for start sequencing, normal stop sequencing, emergency engine shutdown, and other GTGS support functions. The main switchboards provide START and STOP pushbuttons for the GTGS and control and monitoring for the generators and CBs.

Details of operation of a GTGS from a switchboard and details of the distribution system are discussed in chapter 12. This chapter covers the operation of the electric plant from the EPCC where control of all three GTGSs is centralized.

GAS TURBINE GENERATOR SET MONITORING

Each GTGS has sensors that provide remote monitoring of the GTE and the generator. The sensor information is sent to the EPCC in three ways: directly from alarm contact switches, through alarm detector circuits in the generator control panel, or through S/CE No. 1.

Alarms

GTGS alarms at the EPCC include the following.

- Generator AIR TEMP HIGH (149 °F)
- Generator FRONT/REAR BRG TEMP HIGH (195 °F)
- Generator STATOR TEMP HIGH (165 °F)
- Engine ENCL TEMP HIGH (200 °F)
- Engine VIBRATION HIGH (3 mils)
- Turbine INLET TEMP HIGH (TIT) (1880 °F)
- Gen/Reduction Gear LUBO PRESS LOW (7/20 psig)
- Engine/Reduction Gear LUBO TEMP HIGH (150 °F)
- Engine/Reduction Gear LUBO STR ΔP HIGH (9 psid)
- Engine FUEL OIL STR ΔP HIGH (7 psid)
- Engine FIRE

Status Lights

Besides the alarm lights, the EPCC has four status lights for each GTGS.

- RUN—This indicator illuminates when the generator running relay at the switchboard is energized. The relay is energized when generator voltage is present at the generator power leads feeding the switchboard.

- CCS IN CONTROL—This indicator illuminates when the control selector switches at the switchboard and at the LOCOP are in the REMOTE position.

- AUTO STANDBY—This indicator is energized by the EPCC turbine start control logic when the following conditions are met.

1. HP air is available, or the generator run light is illuminated.
2. CCS IN CONTROL—(same as above).
3. The CB mode control selector switch at the switchboard is in the AUTO position. Also, the switchboard and generator control panel permissives are met.

   a. Governor control in NORMAL mode
   b. Voltage regulator control in NORMAL mode
   c. GB open (TRIPPED)
   d. GTG control panel in REMOTE

4. A generator-in-standby signal has been received from EPCC plant-status identification logic. This signal is generated when the plant configuration stored in a logic

memory is one of those for which that generator is in standby. For instance, a generator No. 3 in-standby signal is generated when configuration 1A, 1B, or 1C (figure 9-27) is stored in a logic memory.

5. Governor control is in the NORMAL mode.
6. Voltage regulator control is in the NORMAL mode.
7. Generator breaker is open.
8. The logic is not inhibited by an EPCC self-test.

- FAIL TO START—This indicator is no longer used.

ELECTRICAL DISTRIBUTION SYSTEM MONITORING

The generator status panel at the EPCC (figure 9-25) provides meter displays and alarms that monitor the output of the three GTGSs. An additional section of this panel is for monitoring shore power. Information for this panel originates at the main switchboards.

Meter Displays

Meter displays at the EPCC include

A-C Kilowatts	GTGS 1, 2, 3
A-C Amperes	GTGS 1, 2, 3, and Shore Power
Hertz (frequency)	GTGS 1, 2, 3, and Shore Power
A-C Volts	GTGS 1, 2, 3, Bus Tie and Switchboard

The voltage being displayed on the bus tie and switchboard panel meter depends on the position of the bus tie and switchboard voltage selector switch (EPCC system control panel, figure 9-24). The meter will display the individual signal designated by the selector switch.

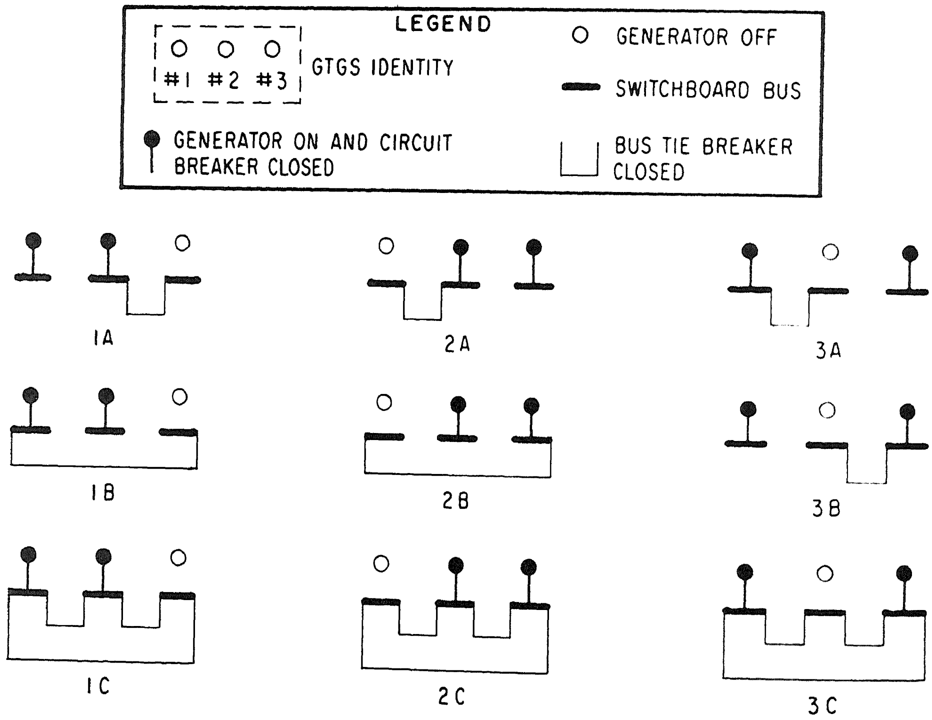

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Figure 9-27.—Standard electric plant configurations.

Alarms

Alarms provided at the EPCC generator status panel include

Generator	HIGH CURRENT	(3200 amp)
Generator	HIGH FREQUENCY	(62 Hz)
Generator	LOW FREQUENCY	(57 Hz)
Generator	HIGH VOLTAGE	(472 volts)
Generator	LOW VOLTAGE	(428 volts)
Shore Power	HIGH CURRENT	(2400 amp)

Shore Power

The shore power phase sequence meter (figure 9-25) receives signals from the shore power bus. When the phase sequence meter switch is on, all three white lights will illuminate. They remain illuminated as long as voltage signals are present for all three phases. The meter will indicate CORRECT PHASE SEQ if the phase rotation between the three inputs is in the correct sequence (ABC). Reverse phase rotation will cause the meter to indicate INCORRECT PHASE SEQ.

A SHORE POWER AVAILABLE indicator of the EPCC MIMIC panel illuminates when the EPCC has received a shore power available signal. The SHORE PWR AVAILABLE and BT 1S-2S ENERGIZED indicators are located on the MIMIC panel (figure 9-23) near the shore power CB pushbutton. Thus, the operator is aware of the status of the two buses before closing the shore power CB.

SWITCHBOARD GROUND DETECTOR

The EPCC alarm status panel has a main switchboard ground detector (figure 9-26). This assembly receives three-phase input and a ground input from ground test transformers at each main switchboard (when each of the switchboard control selectors is in REMOTE position). The EPCC selector switch will connect these inputs (switchboard No. 1, 2, or 3) to the primary side of the indicator light transformer. The three indicating lights will illuminate equally. When the GROUND TEST pushbutton switch is depressed, a ground test relay at the selected switchboard is energized. Then the common lead of the primary windings of the ground transformer on the switchboard is connected to ground. If a ground exists on one of the phases, the indicator for that phase light will go out (or glow dim). This is because the potential across the primary winding of the ground test transformer for that phase will be reduced or eliminated. The other two phase lights will brighten since the voltage across these phases is increased. Release of the GROUND TEST pushbutton switch will de-energize the ground test relay. The circuit will return to normal with all three lights illuminated equally.

SWITCHBOARD EMERGENCY POWER

An EMERGENCY PWR ON indicator light for each main switchboard is located on the EPCC alarm status panel (figure 9-26). Each light receives a signal from its respective switchboard when the switchboard is operating from its emergency power battery bank (24 volts d.c.).

CIRCUIT BREAKER CONTROL

The EPCC provides centralized control and monitoring of the three GBs, the six BTBs, the shore power breaker, and the five load center feeder breakers. The pushbutton indicators for these CBs are located on the EPCC MIMIC panel (figure 9-23). EPCC control of the CBs is established only when the GTG control selector switches at the switchboards are in the REMOTE position. Remote operation of CBs is performed by energizing 28-volt d.c. close and trip relays at the associated switchboard. When a close relay is energized, it completes a 110-volt a.c. circuit in the CB assembly. This energizes the breaker motor to start the closing sequence. When a trip relay is energized, it completes a 110-volt a.c. circuit in the CB assembly. This activates the trip coil and opens the breaker contacts. After the breaker opens, the motor will run to recharge the closing spring, arming the breaker for another closure.

The CB control at the EPCC can be divided into two categories: operator-initiated CB control and logic-initiated CB control. Operator-initiated

CB control is provided on the MIMIC panel through CB pushbutton switch/indicators. The indicators display the CLOSE or TRIP status of the CB during all modes of operation (except when certain sequences of the EPCC self-tests are in program). Control of the load center CBs is available in all modes of operation since no synchronization is required. The load center CBs connect the main switchboards to load centers for further distribution of electrical power. You can operate the CBs and BTBs from the EPCC during either the manual or manual permissive modes.

In the manual mode, the CB commands are sent directly from the EPCC to the open and close relays at the switchboard with no protective interlocking. In the manual permissive mode, CB trip commands are sent from the EPCC just like the manual mode. However, the close commands are not sent directly to the close relays at the switchboard. They are sent through the synchronizing monitor at the switchboard. The synchronizing monitor must be aligned to monitor the particular CB closed or no close command will be sent to the close relay. The synchronizing monitor is aligned by turning the SYNC select switch at the EPCC (when control is at the EPCC). When this switch is set to a particular CB, relays at the switchboard will be energized to align the synchronizing monitor to that CB. The synchronizing monitor will prevent a close command from energizing a close relay unless the difference in voltage between the on-line and oncoming units is less than 22 volts, the frequencies differ by 0.2 Hz or less, and the phase angle difference is between −30 and 0 electrical degrees. This prevents closing of a breaker in an out of synchronization condition.

The CB close commands originate in control logic when the EPCC is in the automatic operating mode. Breaker close commands can be issued as part of an automatic paralleling sequence or by the failure detection and recovery logic during an automatic configuration change. The BTBs 3S-1S and 3S-2S are the only breakers that will trip automatically. The auto trip commands isolate switchboard No. 3 if all three generators are in parallel for more than 2 minutes.

GAS TURBINE CONTROL

Control of the GT is available at the EPCC when the LOCOP and switchboard have been aligned for remote operation.

Start/Stop Control

Manual GTGS control available at the EPCC consists of a START pushbutton, a STOP pushbutton, and an HP AIR/LP AIR GTRB START MODE SELECTOR switch (figure 9-23). You can use the start controls only when the control transfer switches at the LOCOP and the switchboard generator control panel are in the REMOTE position. When a START pushbutton is depressed, a signal is sent to the HP AIR/LP AIR selector switch, which is spring-loaded, to the LP AIR position. A start signal is sent to the HP or LP start relay at the associated switchboard, depending on the position of the EPCC HP AIR/LP AIR selector switch. The energized switchboard relay will send a start signal to the GTG control panel. This begins either the HP air or LP air (as selected) start sequence. The GTGS is started and reaches running speed automatically. Before beginning the LP air start, you must align the starter air system for GTGS starting following the EOSS.

The EPCC STOP pushbutton switch (figure 9-23) is not affected by the control transfer switches. When the EPCC STOP pushbutton is depressed, a signal is sent to the turbine stop relay at the switchboard. This, in turn, sends a stop signal to the LOCOP to begin a normal stop sequence.

The EPCC is capable of automatically generating an HP air start command. It uses the same flow path as a manual HP air start command. The automatic HP air start command is a 1-second signal from the GT start control logic in the EPCC. The command is issued as part of the auto recovery sequence. This sequence is described later in this chapter. The EPCC logic cannot issue an LP start command; also, it cannot generate a signal to stop a GTGS.

Frequency Control

The frequency of each GTGS is controlled by an EG mounted in the associated GCU enclosure

located near the switchboard. The EG senses both the frequency of the PMA attached to the generator shaft and the load demand on the generator. The EG sends signals to a hydraulic actuator on the GT. The actuator adjusts the fuel flow in the engine to maintain engine speed. The EG system will regulate the frequency to a level set by a motor-driven reference potentiometer. When control is at the EPCC, individual frequency adjustment is made by activating this motor in the RAISE or LOWER direction. There are two modes of governor operation, NORMAL and DROOP. The NORMAL mode is isochronous, or constant frequency. The DROOP mode is an alternate mode where frequency decreases with increasing load. The DROOP mode is used for paralleling with shore power. Mode is determined by a latching relay in the associated GCU which can be controlled from the EPCC (when control is at the EPCC). You can find more information on the governor system in chapter 8.

Individual Governor Control

Individual FREQ adjust knobs (figure 9-24) are provided at the EPCC for each GTGS. These controls are disabled when the generators are in parallel, the VR. mode in NORMAL, and the GOV. mode is in NORMAL. When one of the FREQ adjust knobs is turned to the RAISE position, it energizes a relay in the associated switchboard. Then a command is sent to the EG to drive the d.c. motor in the raise direction. The motor will continue to run until the knob at the EPCC is released, or until the motor drive mechanism reaches its limit switch. The motor drives the reference potentiometer and will cause the governor to regulate at a higher frequency. A similar series of events occurs when a LOWER adjustment is made.

The NORMAL/DROOP pushbutton switch/indicator (figure 9-24) at the EPCC is used to select governor mode when control is at the EPCC. Depressing this pushbutton switch changes the state of the isochronous/droop latching relay at the governor. The lights of the indicator will illuminate to show either NORMAL or DROOP, depending on the state of the latching relay.

System Governor Control

When the voltage and governor controls are in NORMAL and the plant is in a parallel configuration, the system frequency control is activated for the parallel machines. The motor-driven frequency adjust potentiometer at each governor is automatically reset to a 60-Hz position. The governors are regulated to maintain equal load balance between the operating GTGSs. Frequency adjustments are then made with the system FREQ knob (figure 9-24) at the EPCC. Positioning this knob to the RAISE or LOWER position will energize the master frequency trimmer motor located in the EPCC. The motor drives a potentiometer which sends an equal trim signal to governors of the parallel machines. This will cause a change in the system frequency without affecting load balance between operating GTGs.

Automatic Paralleling Frequency Control

During automatic paralleling operation, the APD located in the CCS automatically adjusts the frequency of the oncoming GTGS to achieve synchronization. The EPCC must be in the automatic mode for automatic paralleling. All governors will be automatically set to 60 Hz before automatic paralleling begins. The APD adjusts the frequency of the oncoming unit by sending a raise or lower signal directly to the load sensing circuit of the governor. When automatic paralleling is achieved, the APD will remove the adjust signal. The governor will regulate to maintain frequency and load balance between the operating units.

GENERATOR CONTROL

Control of generator field excitation for a GTGS is maintained by its GCU. In the AUTO mode of operation, the GCU regulates the generator output voltage to a level set by a motor-driven reference potentiometer located at the regulator. In the MANUAL mode, excitation current from the GCU is set by a motor-driven rheostat located at the associated switchboard. When control is at the EPCC, voltage is adjusted by operating either the reference potentiometer motor (AUTO mode) or the manual rheostat motor (MANUAL mode) in the RAISE or LOWER direction. There are two modes of

reactive current compensation for the GCU: NORMAL and DROOP. Compensation mode is determined by a latching relay at the associated GCU. You can control the position of this relay from the EPCC (when control is at the EPCC).

Individual Voltage Control

The individual voltage controls (figure 9-24) at the EPCC are used to raise or lower generator voltage when a generator is operating independently. The individual voltage controls are disabled when the EPCC is operating the GTGSs in parallel with VR. and GOV. modes in NORMAL. These controls can function in either of two ways. If the AUTO voltage regulator mode has been selected, the RAISE or LOWER position on the voltage adjust knob will send 28 volts d.c. to the motor-driven regulator reference potentiometer at the GCU. The potientiometer will rotate it in the RAISE and LOWER direction. The voltage regulator will then control generator voltage at a new level. If the MANUAL voltage regulator mode has been selected, the RAISE or LOWER position on the voltage knob will send a 28-volt d.c. signal to the motor-driven manual voltage adjust rheostat at the switchboard. This changes excitation current being supplied to the generator field. The voltage regulator mode is set by a latching relay at the switchboard. You can change the state of this relay (automatic or manual) by depressing the AUTO/MANUAL pushbutton indicator (figure 9-24) at the EPCC (when the EPCC is in control).

System Voltage Control

System voltage control operates similarly to system frequency control. It is in effect only when the plant is in a parallel configuration with VR. and GOV. modes in NORMAL. You can turn the system VOLT adjust knob (figure 9-24) to the RAISE or LOWER position. This will cause the motor-driven reference potentiometer at each operating GTGS to turn equally in the RAISE or LOWER direction.

Automatic Paralleling Voltage Control

During automatic paralleling operations, the APD will automatically adjust the voltage of the oncoming unit to match the voltage of the on-line unit. The APD makes adjustments by sending raise or lower commands to the motor-driven reference potentiometer at the voltage regulator. It does this until the two GTGS voltages are matched. The voltage regulator reference is kept at this new setting after paralleling is achieved.

AUTOMATIC PARALLELING SYSTEM

The automatic paralleling system is used to automatically parallel an off-line GTGS with the energized main bus. Once activated, the system will adjust the generator voltage and engine speed of the oncoming GTGS with the on-line conditions, identify the proper time for CB closing, and then issue a close command to complete the paralleling operation. You can manually start the automatic paralleling sequence at the EPCC system control panel (figure 9-24). Under certain conditions it will be automatically started by the EPCC failure detection and recovery logic. The EPCC must be in the AUTO mode of operation for automatic paralleling operations. In the auto paralleling system, plant status identification and CB control are conducted by the EPCC logic; voltage and frequency monitoring and control are conducted by the APD.

An operator-initiated auto parallel sequence is started when one of three auto parallel pushbutton switch/indicators (GEN 1 & 2 PARALLEL, GEN 2 & 3 PARALLEL, or GEN 1 & 3 PARALLEL) is depressed. Both of the GTGs to be paralleled must be running or the operation will be aborted. The control logic evaluates the paralleling command based on the existing plant configuration. It does this by monitoring the open/closed status of the generator and BTBs. If paralleling cannot occur because of plant configuration, the sequence will be aborted. If the configuration is acceptable, the control logic will identify to the APD the on-line and oncoming units. The APD will then send raise or lower signals to the oncoming generator voltage regulator to match on-line voltage. It will also send raise or lower signals to the oncoming EG to match on-line frequency. When the frequencies and voltages are matched and the phase angles are within ± 15 electrical degrees for about 0.75 seconds, the APD will issue an in sync signal to the EPCC. The EPCC logic will start a GB close command and monitor for a breaker closed status. If the breaker closes within 3 seconds, the

sequence will be completed. The auto parallel indicator will illuminate to signal a satisfactory paralleling operation. The APD will remove voltage and frequency commands. The parallel generator will operate normally, sharing loads and currents. If the breaker does not close within 3 seconds, the GB TRIP indicator will flash. The sequence will abort.

A similar sequence is followed for automatic paralleling started by the failure detection and recovery logic. In a recovery sequence, the GTGS start commands are generated by the recovery logic before a paralleling command is sent to the auto parallel system. Plant status identification and CB control are provided by failure detection logic.

The automatic paralleling function is inhibited when shore power is being used. If all three generators are paralleled, the configuration logic in the EPCC begins a 2-minute time delay. If three generators are still in parallel after this interval, generator No. 3 and its switchboard will be isolated by automatic tripping of BTBs 3S-1S and 3S-2S (figure 9-23).

SYSTEM CONFIGURATION

The electrical system is designed so that two generators can supply all electrical loads. The third GTGS can be put on standby. Then it can automatically be started and synchronized to the bus if one or both of the on-line generators should fail. Automatic failure detection and recovery is available only when the EPCC is in control and in automatic mode. Also, the electric plant must be in a standard parallel or standard split plant configuration.

Standard Parallel Plant Configurations

In parallel plant operations, two generators are on line and paralleled. Also, all BTBs tie CBs are closed to connect the three main switchboards in a loop system. The possible combinations of two paralleled generators are designated 1C, 2C, and 3C as in figure 9-27. Configuration status logic at the EPCC identifies the on-line generators for auto recovery control.

Standard Split Plant Configurations

Standard split plant operation requires that two generators be on line, but not paralleled. The switchboard bus of the off-line generator is energized through the bus tie connection to one of the on-line generator switchboards. The remaining bus ties are not energized. The six possible standard split plant configurations are identified in figure 9-27 as 1A, 1B, 2A, 2B, 3A, and 3B. The configuration status logic at the EPCC can identify any of these configurations by monitoring the open and closed status of the generator and BTBs.

Nonstandard Plant Configurations

The open loop paralleled generator configurations (figure 9-28) energize all three switchboards

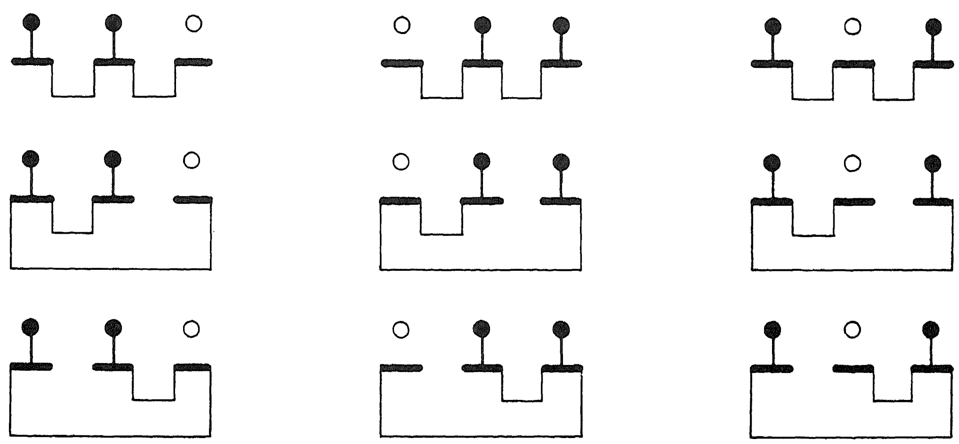

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Figure 9-28.—Nonstandard plant configurations.

with two generators. These configurations are operator selected, or they are the result of a failure. All electrical distribution functions are provided with these configurations, but automatic recovery capability is not available.

Emergency Configurations

Emergency configurations are shown in figure 9-29. Normal plant operation requires two generators in parallel or split plant configurations. In an emergency, with two generators inoperative, one generator must energize the three switchboards. Overpower protection will cause shedding of preselected nonvital and semivital loads. The generators have a 30-minute overload rating of 2200 kilowatts. If automatic load shedding does not reduce loading sufficiently, additional loads will have to be removed manually.

FAILURE DETECTION AND RECOVERY SYSTEM

The failure detection and recovery system is part of the EPCC control logic. It monitors the electric plant for a change in configuration or a failure of an operating GTGS. This control logic can identify a failure, evaluate plant configuration, and begin commands to restore the electric plant to a standard parallel operating configuration. In case the BTBs open while the system is in a standard parallel plant operating configuration, no attempt is made to change the new configuration.

A standard plant configuration is identified and stored in the EPCC logic memory whenever the CONFIG CHANGE RESET pushbutton is depressed. This standard configuration will remain in the memory, regardless of any subsequent change in configuration, until the CONFIG CHANGE RESET pushbutton (figure 9-23) is again depressed. The new standard configuration of that moment will then be stored in the logic memory. If the plant is not in a standard configuration at that moment, none of the nine memories will output a signal.

Automatic failure detection and recovery is available only when (1) the EPCC is in control and in the automatic mode, (2) the electric plant is in a standard plant configuration, and (3) one generator is in AUTO STBY. AUTO MODE ON is activated when the EPCC is in AUTO mode and the voltage regulator and governor are in NORMAL mode.

The response of the system to a particular failure is based on the type of failure and the plant configuration at the time of the failure. Plant configuration is monitored by the plant-status logic that uses contacts at each CB to determine breaker open/close status. A change of status of any BTB or GB constitutes a configuration change. GTGS failures are monitored by the GTGS monitoring circuits of the EPCC which transmit probable failure signals to the failure detection logic. When a failure occurs that leaves the plant in an unacceptable configuration, the recovery logic will try to restore the plant to an acceptable

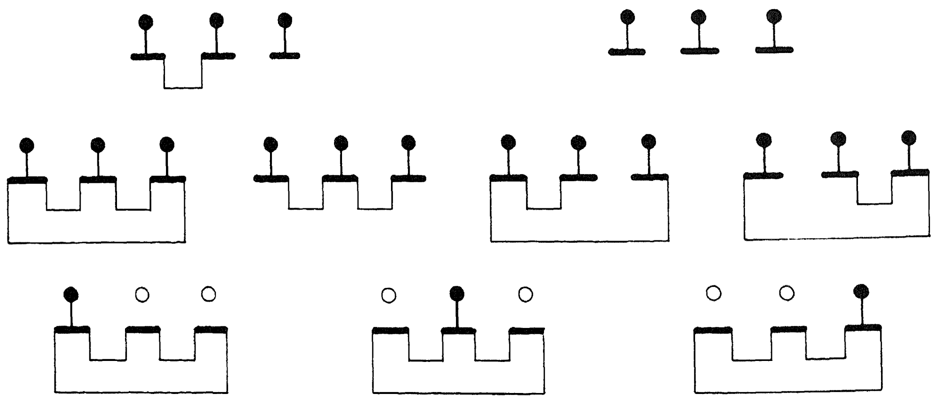

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Figure 9-29.—Emergency configurations.

configuration. This is done by closing BTBs or by starting and paralleling the standby GTGS.

Auto Recovery from Configuration C

Assume the system is in configuration C (figure 9-27) that has GTGSs No. 1 and No. 2 on line, all BTBs closed, and GTGS No. 3 in AUTO STANDBY. The failure detection and recovery logic monitors the plant configuration for change in

1. GB No. 1 closed status,
2. GB No. 2 closed status,
3. BTBs closed status,
4. Generator No. 1 probable failure, and
5. Generator No. 2 probable failure.

A generator probable failure will be started by any of the following GT or generator alarms.

- REAR BRG TEMP HIGH
- STATOR TEMP HIGH
- INLET TEMP HIGH
- ENCLOSURE TEMP HIGH
- AIR TEMP HIGH
- FRONT BRG TEMP HIGH
- LUBO PRESS LOW
- LUBO TEMP HIGH
- VIBRATION HIGH
- FIRE

Consider the case in which GB No. 2 opens. The following events take place.

1. The SYS CONFIG START alarm indicator illuminates flashing.
2. Generator No. 3 is given a start command and a 60-second timer is started. If the logic does not receive a generator No. 3 running signal before the 60 seconds has elapsed, an electric plant No. 3 malfunction signal is generated. Then the AUTO RCVY NOT AVAIL alarm indicator illuminates flashing.
3. The generator No. 3 running signal issues a command to parallel generators No. 1 and No. 3. At the same time, a 32-second timer will start. If the 32 seconds elapses before a generator in sync signal is received, an electric plant No. 3 malfunction signal is generated. Then the AUTO RCVY NOT AVAIL alarm indicator light illuminates flashing.
4. The generator in sync signal begins a close command to GB No. 3 and starts a 3-second timer. If GB No. 3 does not close within 3 seconds, a GB No. 3 failure to close signal causes the AUTO RCVY NOT AVAIL alarm indicator to illuminate flashing. Successful closing of GB No. 3 illuminates the SYS CONFIG CHNG COMPL status light and the AUTO RCVY NOT AVAIL light flashes.

Depressing the ALARM ACK pushbutton switch causes the flashing SYS CONFIG CHNG START and AUTO RCVY NOT AVAIL lights to illuminate steadily.

Depressing the CONFIG CHANGE RESET pushbutton switch resets the logic memory to the new plant configuration. The logic memory identifies the new configuration as 3C. The SYS CONFIG CHNG START and SYS CONFIG CHNG COMPL lights extinguish. The AUTO RCVY NOT AVAIL light also extinguishes if generator No. 2 meets all the requirements of being in auto standby.

If instead, both GBs No. 1 and No. 2 remain closed and there is a generator No. 2 probable failure, the logic commands generator No. 3 to start. It does not issue a command to parallel with the on-line generators. Operator action is required to either correct the generator No. 2 probable failure or replace it with generator No. 3.

If both CBs remain closed and there is no generator probable failure, the logic checks to see if any BTBs have opened. If any BTBs have opened, the SYS CONFIG CHNG START light illuminates flashing. The first BTB to open stores a signal in a logic memory. This causes the SYS CONFIG CHNG COMPL light to illuminate.

Depressing the CONFIG CHANGE RESET pushbutton switch resets the logic memory to the new plant configuration. It will identify the new configuration as being neither 1A, 1B, nor 1C.

This eliminates a generator No. 3 in standby signal. Therefore, the generator No. 3 AUTO STBY light extinguishes. The AUTO RCVY NOT AVAIL light illuminates steadily.

Auto Recovery from Configuration A

Assume that the plant is in the lA configuration (figure 9-27) where generators No. 1 and No. 2 are on line and only BTB 2-3 is closed. The failure detection system monitors the plant configuration for change in

- GB No. 1 closed status,
- GB No. 2 closed status,
- Generator No. 1 probable failure,
- Generator No. 2 probable failure, and
- BTB 2-3 tripped status.

If GB No. 2 opens, the following events take place.

1. A command is issued to close all BTBs.
2. The SYS CONFIG CHNG START light illuminates flashing.
3. Generator No. 3 is given a start command and a 60-second timer is started. If the logic does not receive a generator No. 3 running signal before the 60 seconds has elapsed, an electric plant No. 3 malfunction signal is generated. The AUTO RCVY NOT AVAIL light illuminates flashing.
4. The generator No. 3 running signal issues a command to parallel generators No. 1 and No. 3. At the same time, a 32-second timer starts. If the 32 seconds elapses before a generator in sync signal is received, an electric plant No. 3 malfunction signal is generated. The AUTO RCVY NOT AVAIL light illuminates flashing.
5. The generator in sync signal begins a close command to GB No. 3 and starts a 3-second timer. If GB No. 3 does not close within 3 seconds, a GB No. 3 failure to close signal causes the AUTO RCVY NOT AVAIL light to illuminate flashing. Successful closing of GB No. 3 illuminates the SYS CONFIG CHNG COMPL light. The AUTO RCVY NOT AVAIL light illuminates flashing.

Depressing the ALARM ACK pushbutton switch causes the flashing SYS CONFIG CHNG START and AUTO RCVY NOT AVAIL lights to illuminate steadily.

Depressing the CONFIG CHANGE RESET pushbutton resets the logic memory to the new plant configuration. The logic memory identifies the new configuration as 3B. Then the SYS CONFIG CHNG START and SYS CONFIG CHNG COMPL lights extinguish. The AUTO RCVY NOT AVAIL light also extinguishes if generator No. 2 meets all the requirements of being in auto standby.

Consider the case in which GBs No. 1 and No. 2 remain closed in the 1A configuration and there is no generator probable failure. The EPCC logic in this case checks to see if BTB 2-3 is open. If BTB 2-3 has opened, the SYS CONFIG CHNG START light will illuminate flashing. A command will be issued to close BTB 1-3 and BTB 3-1. Closing of these breakers causes the SYS CONFIG CHNG COMPL light to illuminate. The AUTO RCVY NOT AVAIL light will still be illuminated since BTB 3S-2S is still closed. Opening this breaker will cause this light to extinguish, and generator No. 3 will then be in AUTO STANDBY with AUTO RECOVERY available.

LOAD SHEDDING SYSTEM

Manual initiation of load shedding is accomplished from the alarm status panel of the EPCC by depressing the pushbutton switch/indicator LOAD SHED ACTIVATED. This switch transfers 28-volt d.c. power to a load shedding control relay in switchboard 2S. The LOAD SHEDDING ACTIVATED indicator on the pushbutton switch at the EPCC illuminates.

Automatic load shedding is started by any overpower sensor circuit (one in each switchboard) energizing a self-contained relay whose contacts are in parallel with the EPCC pushbutton switch/indicator LOAD SHED ACTIVATED. Closure of these contacts energizes the same load shedding control relay in switchboard 2S. The LOAD SHEDDING ACTIVATED indicator on the pushbutton switch on the EPCC illuminates.

When the load shedding control relay is energized, its contacts pick up tripping relays in each main switchboard. The tripping relays complete power circuits to the trip coils on selected main switchboard CBs. The coils open the CBs to remove load from the line. Additionally, other loads are similarly inhibited in load center switchboards by activation of tripping relays by their load shedding control relays.

The tripping relay also provides power to a time delay relay in each main switchboard. The time delay is 5 seconds. If either the EPCC LOAD SHED ACTIVATED pushbutton switch/indicator or the overpower sensor is activated for 5 seconds, the time delay relay is picked up. The contacts of this relay pick up additional equipment CB trip coils and, consequently, further reduce load.

Use of the EPCC LOAD SHED ACTIVATED pushbutton switch/indicator or overpower sensor detection of overloads is referred to as first stage load shedding. After 5 seconds of either of these activations, second stage load shedding is entered.

UNINTERRUPTIBLE POWER SYSTEM

The EPCC alarm/status panel (figure 9-26) provides monitoring for the emergency power source, referred to as the UPS. Four alarm indicators are on the panel associated with the UPS system.

1. MAIN ENGINE ROOM NO. 1—Indicates control equipment in that space is operating on UPS.

2. MAIN ENGINE ROOM NO. 2—Indicates control equipment in that space is operating on UPS.

3. BATTERY CHARGING—Indicates current is being supplied to the UPS battery bank by the UPS battery charger.

4. BATTERY LOW VOLTS—Indicates voltage at the battery bank is low (about 120 volts).

THE 60/400-HERTZ POWER SYSTEM

The three 60/400-Hz, three-phase converter units each provide a shutdown signal, a summary temperature high signal, and a power available signal to the EPCC alarm status panel (figure 9-26). All signals are activated from relays in the 400-Hz power distribution switchboards. The SHUTDOWN warning indicating light is illuminated when the power available relay is de-energized. The SMY TEMP HIGH warning indicating light is illuminated when either the high temperature or the cooling failure relay is energized. The POWER AVAILABLE illuminates when the power available relay is energized.

PROPULSION AND AUXILIARY MACHINERY INFORMATION SYSTEM EQUIPMENT (PAMISE)

The PAMISE has the following components.

- Central Information System Equipment (CISE)

- Signal Conditioning Enclosures (S/CEs) 2 and 3 (located in the MERs)

The PAMISE is used to monitor the propulsion plant, electric plant, and selected ship's auxiliaries. It also provides printed bell and data logs and operator data.

CISE MONITORING

The CISE is located in the CCS. The components that make up the CISE include the executive control unit (ECU), S/CE No. 1, two printers, and the associated power supplies. The ECU is the main component of the system. It is a special purpose computer used to collect, analyze, and distribute data for use by the operators of the engineering plant. The ECU gathers data from the ship's equipment by collecting inputs from the S/CEs, PAMCE, and EPCC. Data is outputted to the operators in the form of alarms, status indicators, printed logs, and digital displays. No propulsion plant control is accomplished in the ECU.

The ECU has a monitor and control panel (figure 9-30) that allows operator logging requests, demand display information, and date/time information. This panel is mounted on the front of the ECU. Another control panel, the ECU test panel, (figure 9-31) (located on the rear of the ECU) is used by maintenance personnel when performing maintenance on the computer.

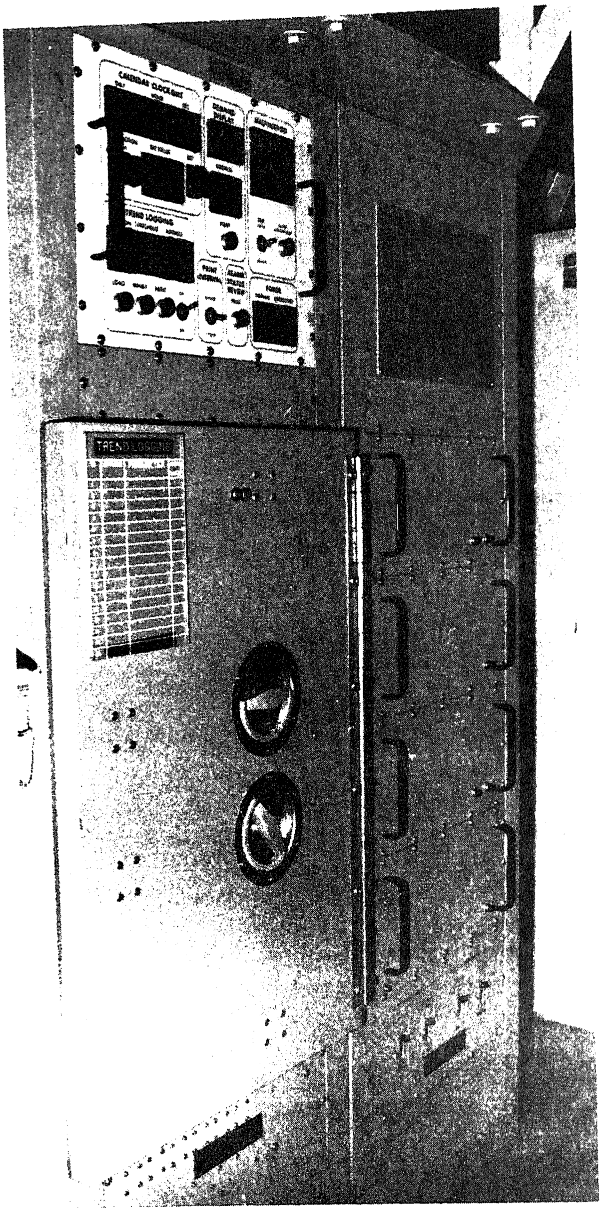

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Figure 9-30.—ECU monitor and control panel.

Monitor and Control Panel

The monitor and control panel of the DD-963 CISE (figure 9-30) is divided into seven sections.

- Calendar/GMT clock
- Demand display
- Malfunction
- Trend logging
- Print interval
- Alarm status review
- Power

CALENDAR/GMT CLOCK.—This section contains a Julian calendar display and a Greenwich mean time digital clock. Julian dates are numerically sequential days of the year. For example, January first is day 001; January second is day 002; December thirty-first is day 365 (except in a leap year when it is day 366). A GMT clock allows logging to be consistent from time zone to time zone without having to note time changes. (NOTE: Ship's policy may dictate logging in local time, and the clock may be set to any time zone.)

Controls are available for setting the clock and calendar. You will find instructions for setting these in your ship's EOP.

DEMAND DISPLAY.—A DDI is located on the monitor. This display allows operators to display a selected parameter by setting up the address on the thumbwheels. Like all other DDIs, you can select and display any plant parameter if it has a DDI address.

A PRINT pushbutton is also associated with the DDI on the CISE. Depressing this pushbutton causes the parameter selected by the address to be printed on the data log. The DDI index also has special addresses that allow group printouts to be printed on the data log. Printouts of groups include areas such as power train, fuel oil, lube

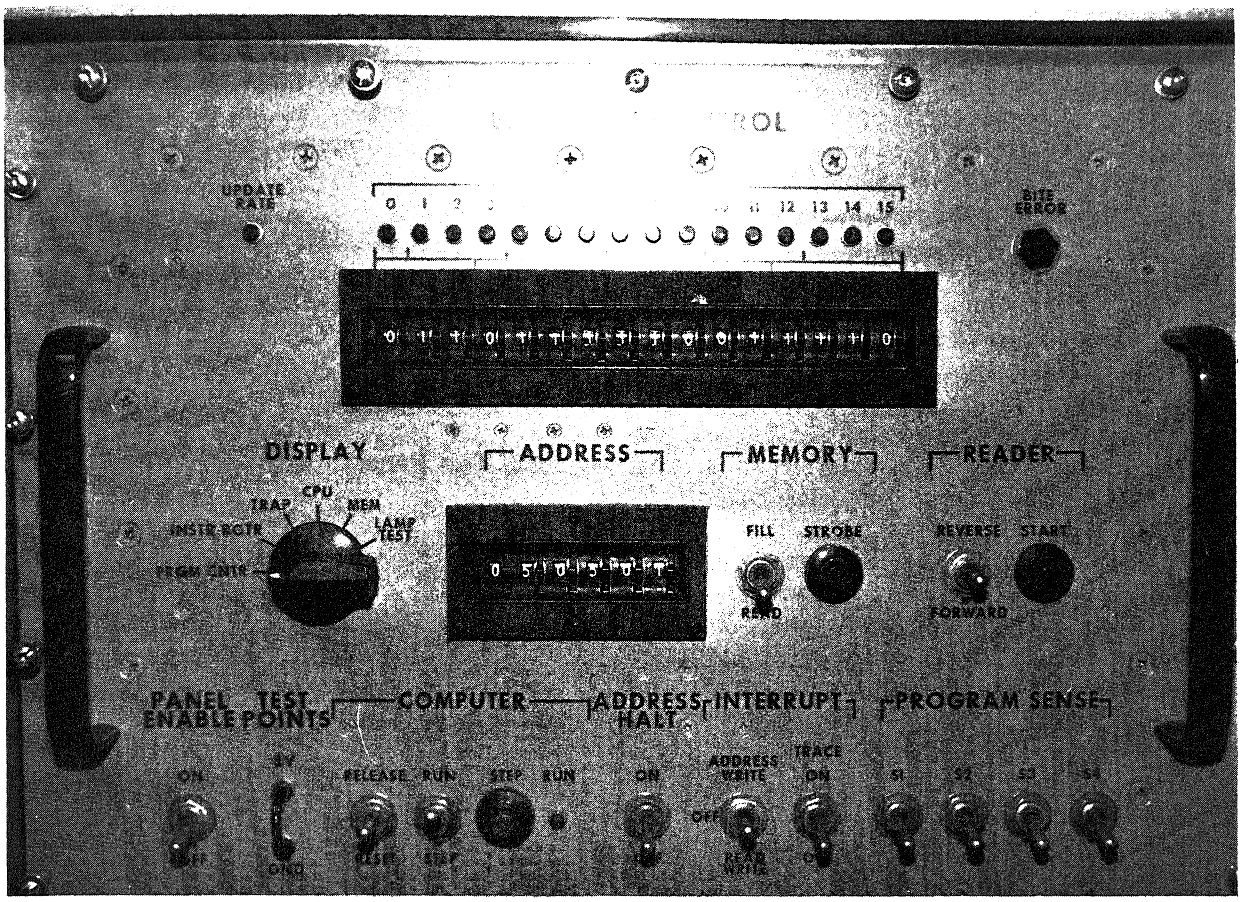

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Figure 9-31.—ECU test panel.

oil, GTM, GTG, and 60-Hz distribution. Consult your DDI index for the addresses of these printouts.

MALFUNCTION SECTION.—The malfunction section has ten indicators, an acknowledge pushbutton, and an alarm/status test switch. These alarms alert the operator when malfunctions occur within the PAMISE system. The ten malfunction alarms include

- ICC-S/CE 1
- S/CE No. 2
- Power Supply
- Bell Logger
- Bell Logger Paper Low
- ICC No. 2
- S/CE No. 3
- Clock Not Set
- Data Logger
- Data Logger Paper Low

When a malfunction occurs in one of these areas, the alarm will flash and a buzzer will sound. Depressing the ALARM ACKNOWLEDGE pushbutton will silence the buzzer and cause the indicator to come on steady. The alarm indicator will extinguish when the malfunction is cleared.

TREND LOGGING.—The trend logging feature of the CISE allows certain parameters to be printed onto the data log when a selected limit is exceeded. The trend logging section has three groups of thumbwheels, three pushbuttons, and an on/off switch. The three thumbwheel groups are labeled FUNCTION, THRESHOLD, and ADDRESS. The function thumbwheel picks 1 of 16 trend logging memory locations. The threshold allows you to preset the amount of variance of the parameter before printout occurs. This range is set between 1 to 10 percent of full scale. The address section is used to select the parameter to be trend logged.

The three pushbuttons labeled LOAD, INHIBIT, and PRINT are used when setting, securing, and reviewing the trend logging. By turning the trend logging on with the toggle switch, you program the trend logging functions with these pushbuttons and the thumbwheels. To use trend logging, you must program it. You may use any or all of the 16 functions. To program a parameter, first, you select a function not being used on the function thumbwheel. Next, you set in the alarm threshold. For instance, if you are logging a parameter whose range is 0 to 200 psi, for every 2-psi change a 1-percent threshold prints out. For every 20-psi change a 10-percent threshold prints out. Third, you must set in the address of the parameter to be logged. After setting all the thumbwheels, you depress the LOAD pushbutton to program the selected parameter into trend logging.

The INHIBIT pushbutton is used to stop logging one of the functions. To stop a function, you select the function on the thumbwheel and depress the INHIBIT pushbutton. If you depress the PRINT pushbutton, the data logger prints out all active functions. This allows you to observe all parameters being monitored.

Normally, trend logging is not used all the time. It is useful for monitoring recently repaired equipment, such as a new bearing, to establish trend data. It is also useful for logging data during full power and economy trials.

PRINT INTERVAL SWITCH.—The PRINT INTERVAL switch sets the interval when the data logger will print a complete plant printout. You may set it for 1 hour or 4 hours depending on ship's instructions.

ALARM STATUS REVIEW.—The ALARM STATUS REVIEW pushbutton commands the data logger to print out all active alarms in the ECSS. This function is useful for the EOOW to review the active alarms and out-of-limits parameters before relieving the watch.

POWER SECTION.—The power indicators allow you to monitor the status of the power supplies in the PAMISE system. They indicate whether CISE, S/CE 2, and S/CE 3 are on normal SS power or on UPS.

ECU Test Panel

The ECU test panel (figure 9-31) is located inside the CISE enclosure at the back of the CISE cabinet. The test panel is the primary interface to the ECU. Through this panel (operated only by experienced GSEs) the computer program is loaded, run, and maintained. Specific instructions on the use of this panel are found in the PAMISE technical manuals. The potential for causing malfunctions to the entire ECSS network by operation of this panel by inexperienced maintenance personnel is very high. You must have a thorough understanding of the serial data networks, binary logic, and digital equipment before operating functions of the ECU test panel.

ECU Operation and Programs

The ECU of the PAMISE is a general purpose stored-program digital computer. It accepts data representing operating values and status of the ships' propulsion, electrical, and auxiliary machinery. The data is processed, scaled to engineering units, and sent, if required, to the digital display or the bell and status/alarm loggers. The sensory information leaving the S/CEs is on a scale of 0 to 1000. If the engineering units are on a scale of 0 to 600, the computer must recognize that it has to multiply, or scale, this input from the S/CE by a conversion factor of 0.6. The computer does these tasks under direction of its stored program called the ECU program. This program is entered into the

computer memory by a tape reader. The program has seven major functions or subprograms.

- Executive
- Bell Logging
- Alarm Logging
- Change of Status Logging
- Trend Logging
- Data Logging
- Self-Test

Each subprogram can be requested in a variety of ways. When a subprogram is called up and working, it is called a task. A task has smaller jobs or pieces of work called routines. This discussion will be limited to the task level description for program analysis.

EXECUTIVE SUBPROGRAM.—The executive subprogram directs and organizes the activities of the computer. The following tasks are performed.

1. Responds to hardware interrupts. A hardware interrupt is performed when an output or input device tells the ECU it needs information or it is ready to give the ECU information. An example of this is when the matrix printer is performing a data log. The ECU provides the printer with only a small portion of the total log (one line); hence, the printer must tell the ECU (interrupt) when it is ready for more information.
2. Schedules tasks to be performed in priority order. This order is

   a. Bell Logging
   b. Alarm Logging
   c. Change of Status Logging
   d. Trend Logging
   e. Data Logging
   f. Self-Test

The program is written so that if a data log is being performed and a bell log (higher priority) is requested at the next interrupt in the data log, the bell log will be picked up and performed. The data log will be shelved for the duration of the bell log, and then resumed.

3. Inputs parameter data and status.
4. Services the demand displays.
5. Begins the start and restart of all routines (a set of routines makes up a subprogram).
6. Handles operator requests for various types of logging.
7. Outputs self-test status words.

BELL LOGGING SUBPROGRAM.—The bell logging subprogram has the responsibility for performing the following tasks.

1. Each second the status of the five parameters below are checked to determine if one or more of them have changed. If a change is found, an output of one print line is formed. It gives the date and time and the current status of the following five parameters.

   - Station in control of port shaft
   - Station in control of starboard shaft
   - Ordered plant mode
   - Port shaft throttle mode
   - Starboard shaft throttle mode

2. When an order or acknowledgement of the standard order EOT occurs for either port and/or starboard shafts, an output of two print lines is formed. The first line has the date and time, the port order and/or acknowledgement, and the actual values of port shaft rpm and propeller pitch. The second line has the starboard order and/or acknowledgement and the actual values of starboard shaft rpm and propeller pitch.
3. Each second the rpm and pitch settings from the EOT (digitized) for both shafts are checked for changes greater than specified limits. If a limit is exceeded for a predetermined length of time, two print lines are formed. The first print line has the date and time, the port rpm and/or pitch settings that changed, and the actual values of port rpm and pitch. The second line has the starboard rpm and/or pitch settings that changed

and the actual values of starboard rpm and pitch. These stored limits for an EOT change are

RPM change	±5 rpm
RPM time delay	5 seconds
Pitch change	±5 percent
Pitch time delay	5 seconds

4. Each second the actual rpm and pitch for both shafts are checked for changes greater than the stored limits. If such a change is found, two print lines are formed. The first line has the date and time and the value(s) of port rpm and/or pitch that changed. The second line has the value(s) of starboard rpm and/or pitch that changed. These stored limits for an actual rpm or pitch change are

RPM change	±5 rpm
RPM time delay	15 seconds
Pitch change	±5 percent
Pitch time delay	15 seconds

ALARM LOGGING SUBPROGRAM.—The alarm logging subprogram can perform one of two tasks listed below.

1. Each second the alarm status of each parameter is compared with the alarm status of that parameter from the previous 1-second check. For each change found (there may be more than one), a print line is formed with date and time, parameter that went into or out of alarm, parameter's value (if analog input), condition of parameter (high/low), and is prefixed with title of log (alarm) and if parameter went out of alarm (reset).

2. On operator demand, a search is made for each parameter that is presently in an alarm state. A print line is formed for each parameter in alarm with information similar to that given above (1) but is prefixed with the title of Alarm Review. This is known as an Alarm Status Review.

CHANGE OF STATUS SUBPROGRAM.—A change of status subprogram monitors the state (on/off, open/close) of those parameters selected by the subprogram. If a change is detected, a print line is formed (one line per parameter). It has date and time, parameter, state or condition of that parameter, and is prefixed with the title of Status Changed.

TREND LOGGING SUBPROGRAM.—The trend logging subprogram has 16 tasks. Each can monitor an operator-selected parameter (one parameter per task). This provides a one-line printout if a parameter exceeds an operator-selected threshold value (1 to 10 percent of that parameter's span; note, zero on the thumbwheel is 10 percent). The program can have any of the 16 parameters or tasks inhibited at operator discretion. The subprogram forms an output line with date and time, parameter, value, and is prefixed with the title Trend. The operator can request a listing of all functions (up to the 16) to be entered into the trend logging subprogram. In this listing, each line contains the information listed above with the exception that a function listing number (1 through 16) is included and the title is changed to Trend Review.

DATA LOGGING SUBPROGRAM.—The data logging subprogram provides for four types of data output or tasks as follows.

1. The data log normal task is started at either 1-hour or 4-hour intervals (operator-selected) on the hour. The log has a printout of all parameters and status inputs and is prefixed with the title Data Log.

2. The data log demand task is started by the operator by activating the PRINT pushbutton at either the PACC or CISE with a DDI number of 800 entered at the respective DDI. The output is similar to that of a data log normal task except that it is prefixed with the title Demand Log.

3. The data log group task is started by the operator by activating the PRINT pushbutton at either the PACC or CISE with a specific DDI number between 801 and 899 entered at the respective DDI. The output is prefixed with the title Demand Group Log. Specific 800 series DDI

numbers that produce equipment group printouts are

Gas Turbine Module

1A = 801

1B = 802

2A = 803

2B = 804

Gas Turbine Generator Sets

#1 = 811

#2 = 812

#3 = 813

60-Hertz Power Distribution

Switchboard 1S	= 821
Switchboard 2S	= 822
Switchboard 3S	= 823
Bus Tie	= 847
Fuel Oil (service)	= 851
Lube Oil	= 861
Power Train	= 841

4. The data log single entry task is started by the operator activating the PRINT pushbutton at either the PACC or CISE with a DDI number for the parameter wanted entered at the respective DDI. The printed output in this task is not prefixed with a title for this log.

SELF-TEST SUBPROGRAM.—The self-test subprogram performs the following six tasks.

1. Sums the contents of all the memory locations that are fixed and not modified by the program. This summation is compared with a reference sum.

2. Writes a predetermined set of test words into a memory location, reads it back out, and then compares the readout with the word as it was written in. Each location is exercised by this set of test words or patterns before proceeding to the next location. This test is done only to those portions of the memory that can be program modified.

3. Computes the alarm status of each parameter and compares it with the alarm status given from the S/CEs.

4. Uses the test bit information from each A/D converter in each S/CE and the data representing the parameter value to analyze possible hardware faults.

5. Checks reference voltages used by various portions of the PAMISE.

6. Analyzes the results of the above tests to determine and indicate in which enclosure the failure occurred and what printed circuit card in that enclosure failed.

SIGNAL CONDITIONERS

Signal conditioning is done by the PAMISE at the S/CEs No. 1, No. 2, and No. 3. The purpose of these S/CEs is to convert all the sensory inputs into a common electrical range of 0 to 10 volts d.c. This is done to make them compatible with the rest of the ECSS. S/CE No. 1 monitors the electric plant and auxiliary parameters; S/CEs No. 2 and No. 3 monitor the main propulsion parameters. Six basic types of signal conditioning done are

1. voltage signal conditioning,
2. current signal conditioning,
3. RTE signal conditioning,
4. tachometer/frequency signal conditioning, and
5. wattmeter signal conditioning.

Each of the above conditioners receives a sensor or external signal conditioner voltage, current, ohmic, or frequency, respectively. These inputs are converted to a 0- to 10-volt d.c. analog signal. These signal-conditioned parameters are processed by other electronic circuitry of the ECSS for alarm generation, analog meter displays, and digital demand displays. The other electronic circuitry by which this 0- to 10-volt d.c.

signal is processed and paths by which the information flows will be discussed with each topic. Discrete contact sensor signals are allowed to pass through the signal conditioners unaffected.

INTERCONSOLE HARDWIRE COMMUNICATION

A limited number of control and indicator signals of the ECSS consoles are communicated between consoles by hardwire or direct link. A summary of these controls and indicators follows.

1. Emergency control at the PACC to the PLCC

2. Throttle/pitch controls at the SCC to the PACC and the PACC to the PLCC

3. Clutch/brake manual control at the PACC to the PLCC

4. Service tank valve control at the PACC to the PLCC

5. Bleed air control at the PACC to the PLCC

6. Analog meter signals from the S/CE to consoles

7. Most indicator lights from the S/CE to the PLCC

SERIAL AND PARALLEL DATA COMMUNICATION

Most of the control and status information communicated between the ECSS control consoles is exchanged in the form of binary signals (these are discrete one of two state signals, characterized by voltage levels and indicating conditions such as on/off). These signals are in groups or arrays of information known as data words. Each binary signal within the data word is called a data bit. It has a binary zero or a binary one logic value. The number of data bits in a data word is referred to as the word bit length. The data words can be exchanged in parallel or serial format.

Parallel Format

In this format, the data transmitting and receiving electronics hardware must have one data line (wire) for each data bit. For example, a 10-bit data word requires 10 data lines. In parallel data word transmission and reception, each bit of the data word is presented at the same time on the data lines. Therefore, the entire data word is sent or received at the same time. Parallel format is used only for data communication within a console to allow more rapid communications and transfer of information. It is also used to minimize the electronic hardware required.

Serial Format

In serial format, data bits are sent and received one at a time. This is done in a timed sequential manner using a single data line. Serial format is used for data communication within a console and between consoles. The data line between consoles is time shared. Clock synchronization between consoles permits information exchange control. Two major types of data lines for serial data transmission are the command and control serial data system and the demand display serial data system. The advantage of serial data format is the substantial reduction of the amount of wiring required for communications.

The command and control serial data system (figure 9-32) is an electrical loop system with a synchronizing bus, clock bus, and data bus. This data bus carries information about plant status/alarms, EOT commands, and plant equipment commands. Figure 9-32 shows what type of information originates from each console (except the CISE which only receives information off this data bus) and is placed on the serial data bus. For example, the PACC originates the following types of information.

- Auto/manual GTM commands

- EOT acknowledgement

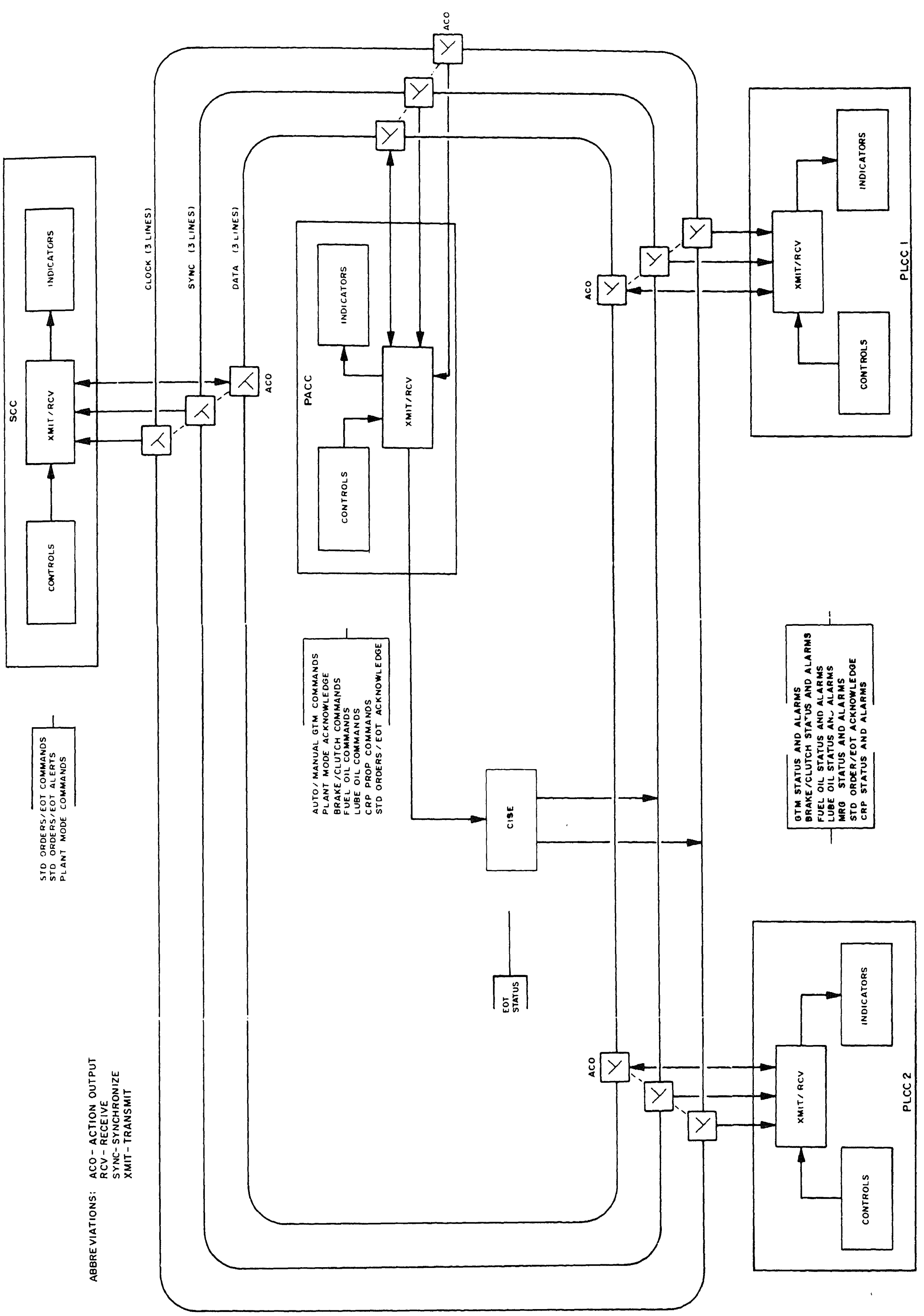

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Figure 9-32.—Command and control serial data network.

- Brake/clutch commands
- Fuel oil commands
- Lube oil commands
- CRP propeller commands

The EOT acknowledge signals from the PACC are received by all consoles and CISE. The equipment commands, however, are received by that particular PLCC controlling that equipment. An example of this would be the fast-slow-stop signals of the fuel oil service pump generated by the PACC operator.

NOTE: The serial data bus has equipment status and alarm information that originates from the PLCCs. Most of the alarm information, in turn, comes from the S/CE associated with that PLCC; most of the status information comes from the plant equipment. It is important to recognize that the S/CEs do NOT directly send information onto the command and control data bus.

The CISE receives plant equipment status and EOT order/acknowledgements off this serial data bus for logging purposes. An example of equipment status information is lube oil pump A fast. NOTE: The CISE does *not* send data information onto the command and control data bus.

This serial data system is a time-shared bidirectional information bus network used to exchange command and control data between the ECSS consoles of the PACC, PLCC No. 1, PLCC No. 2, SCC, and the CISE. Each of the three buses has three separate lines or conductors. That is, the data bus has three lines, as does the clock sync buses. Each of these three lines carries the identical binary information data simultaneously; but, they are associated with three separate cable runs routed through different geographic areas of the ship: port side, center, and starboard side. The triple redundant lines serve to increase and maintain system communication reliability if a cable casualty occurs. Two cables, however, are required for system operation.

The command and control data listed alongside each console in figure 9-32 is exchanged in the form of 16-bit serial data words. Twelve bits of each word are used to convey control information. The remaining four bits are used for parity indication and time spacing between serial data words. Each serial data word has a word period length of 1.95 milliseconds. Each control console of the ECSS sends command and control data onto or receives command and control data off of the serial data loop during certain fixed time periods within each second of system operation. Exceptions to this are that (1) PAMISE and the EPCC do not send data on the command and control data bus, and (2) the EPCC does not receive information off the command and control data bus.

One second of system operation is divided into four 250-millisecond word blocks. Each word block is further divided into 128 individual word periods. One word period is therefore, as mentioned earlier, 1.95 milliseconds in length. A maximum of 512 serial data words per second can be exchanged over the command and control serial data bus between the consoles of the ECSS. This network is shown in figure 9-32. Figure 9-33 shows the relationship of word periods and word blocks to 1 second of system operation.

The serial data loop is a time-shared system wherein only one console at a specific time can transmit onto the data bus. However, more than one console, including the transmitting console, can be receiving the same transmitted data at the same time. Serial data logic circuitry within each console is used with the system clock located in the PAMISE. This system clock controls the timing of the console sending and receiving circuits.

As shown in figure 9-32, the PACC, PLCC No. 1, PLCC No. 2, and the SCC are each connected to the sync, clock, and data buses and hence interconnected to each other. This connection is done through an action cutout (ACO) switch assembly associated with each console. Each ACO is connected to two adjacent ACO switches. The order of connection is unique. For

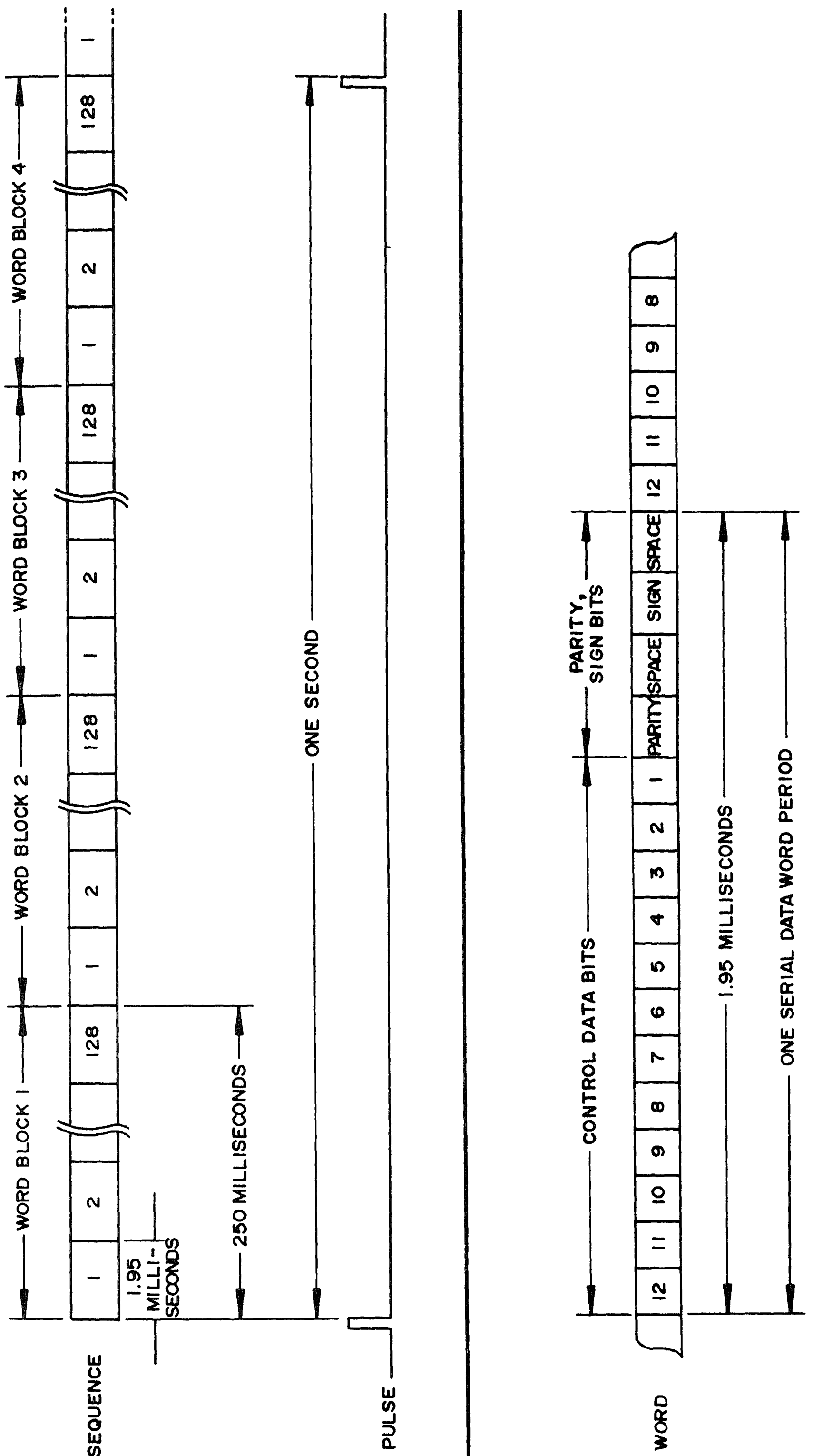

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Figure 9-33.—Serial data word blocks and word periods.

example, the SCC ACO connects to the PACC ACO and PLCC NO. 2 ACO; the PACC ACO connects to both the SCC ACO and to the PLCC NO. 1 ACO, and so forth. Thus, each console has two alternate communication paths with the other units on the serial bus loops. The ACO switch has the following four different functional positions.

1. Normal—Console connected through ACO switch to both adjacent consoles.

2. Adjacent Disconnect—Console disconnected from adjacent console on loop. Two positions are on the switch, one for each adjacent console.

3. Electrical Disconnect—Console disconnected from loop, but loop continuity is maintained through the ACO switch.

4. All Disconnect—Console disconnected from each adjacent console.

If a console is disconnected from one of its adjacent consoles, communication between the two consoles will not be disrupted as the alternate input/output connection can still provide such communication via the remaining adjacent unit. For example, if the PLCC No. 1 ACO is disconnected from the PACC ACO, communication between the two consoles can still occur via the path from the PACC, through the ACO at the SCC, through the ACO at the PLCC No. 1, and finally to the PLCC No. 1. The ACO switch assembly is used primarily for maintenance purposes. It is used to isolate a console completely from the serial data loops or to isolate a certain interconsole segment of the data loop from the system.

The demand display serial data system (figure 9-34) is separate from, but similar to, the command and control serial data system. It interconnects the CISE, PACC, PLCC No. 1, PLCC No. 2, and the EPCE. It is used only for digital display information exchange. Separate sets of triple redundant data lines are used for connecting CISE with the other consoles in the demand display serial data system. (See figure 9-34.) Digital addresses of propulsion, auxiliary, and electric plant system parameters are multiplexed and serially sent via the data lines to CISE by each of the listed SCCs. This is done during certain fixed time periods within each second of system operation. The ECU (1) receives and decodes the 16-bit serial parameter address, (2) retrieves the value of the demanded parameter from computer storage, and (3) serially sends the parameter value back to the proper control console for digital display.

For example, if the PACC operator needed to know the hp output of the GTM 2A, the operator would refer to the sensor index on the PACC and find the address needed to read that parameter. For the GTM 2A, this address is 129. The operator would then enter that address into the thumbwheel switches at the digital display chosen. The address is sent to the ECU. The ECU retrieves the value of that parameter from its memory associated with that address. The ECU obtains this data in memory from the S/CEs. The ECU then sends that data back to the digital display that requested it.

The digital display does not provide the engineering units or the multiplier. Both the engineering units and multiplier are given with the sensor index on the console. Engineering units are the physical units associated with that address such as hp or psig. The multiplier locates the decimal point. In the example given, it is ×100. This means that the operator must multiply the reading on the digital display by 100. The address tables at the consoles are sectionalized into air control, electric plant, GTM, and so forth. The tables list the parameter name, demand display address, associated alarm set point (if any), and whether the alarm point is a low- or high-level alarm.

Synchronization

Synchronization within the command and control and demand display circuits contained in the PAMISE, PACC, PLCC No. 1, PLCC No. 2, EPCC, and the SCC is maintained by system sync pulses and 8192 hertz clock pulses. These sync pulses are generated by a master clock circuit. They are sent to th

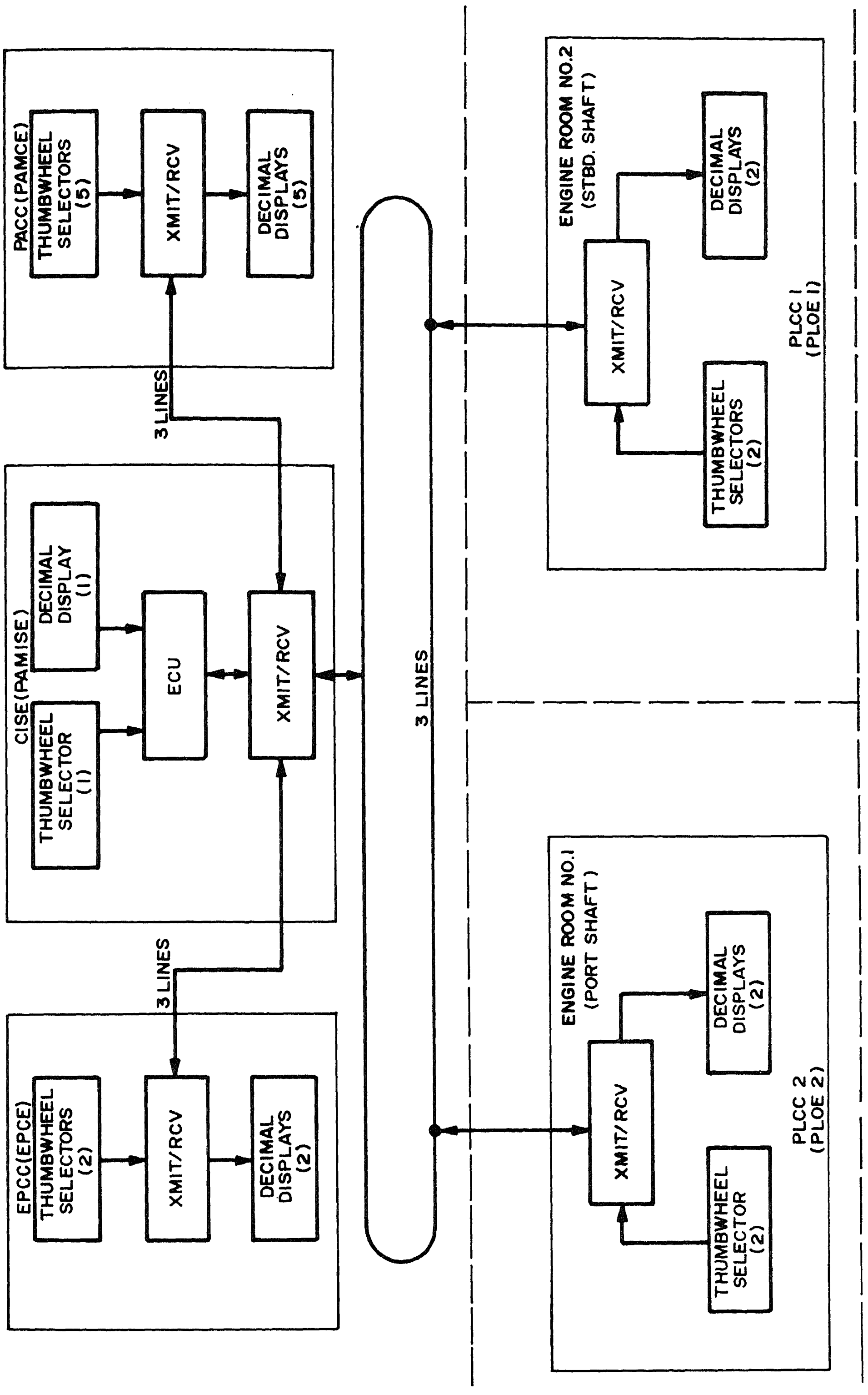

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Figure 9-34.—Demand display serial data system.

various control console serial data circuits (figure 9-35).

The system sync pulse, generated at one pulse per second (pps), is 122 microseconds in duration. As applied in this chapter, a pulse is a repetitive voltage signal of a fixed period which varies from a logic zero to a logic one. The trailing edge of this sync pulse shows time zero of each second of the serial data loops operation.

The hertz clock pulses are used for timing serial data electronic circuitry within each console. That is, the clock pulses allow timing of transmission of the proper information and delivery of received information to its proper destination.

The system master clock circuit is located in the S/CE No. 1 of PAMISE. It sends the synchronization signal to the remainder of the ECSS consoles over a system sync and clock bus network. Identical master clock circuits are in the PLCC No. 1 and PLCC No. 2. They automatically take over series data system synchronizing function if the S/CE No. 1 clock fails. The takeover circuitry is designed so the PLCC No. 1 takes over if the S/CE No. 1 fails; the PLCC No. 2 takes over if the PLCC No. 1 fails.

DATA PROCESSING

The objective of this section is to provide a functional analysis of alarm generation and distribution of data for display and logging. This description analyzes the information flow after the sensory inputs have been signal conditioned (which was discussed earlier).

Alarm Monitoring

Alarm monitoring is performed on some of the engineering plant parameters. After these parameters have been signal conditioned (0 to 10 volts d.c.), they are connected to alarm detector electronics located in the proper S/CE unit. The alarm detector compares the conditioned sensory input voltage to an alarm set point voltage. If this alarm set point is exceeded by the sensory input value (high alarm), an alarm signal is generated. It is routed to the ECU to provide for a printed record. The signal is also routed to provide an audible alarm (horn or siren) and illuminate the proper flashing light indicator. The alarm is a low alarm when the alarm set point value exceeds the sensory input value.

The output of the alarm comparators of S/CEs No. 2 and No. 3 provide hardwire alarm signals to its associated PLCC. Those of S/CE No. 1 provide hardwire alarm signals to the EPCC and the auxiliary panel of the PACC. This alarm output signal causes the proper indicator light to flash and either the horn or siren to sound. The alarms at each PLCC are duplicated at the PACC. The PACC receives the alarm information from each PLCC via the command and control serial data bus. The output alarm signal of the alarm comparator at S/CEs No. 2 and No. 3 are also serially transmitted. This is done by a separate data bus to the ECU to start an alarm log. The S/CE No. 1, however, sends the alarm signals in a parallel format to the ECU to begin the alarm log.

The ECU also functions as a backup alarm detector when failure of an S/CE alarm detection circuit occurs. Since the ECU extracts the sensor input value before the alarm detection circuit, it will compare this value to the alarm set point value stored in memory. If the sensor value exceeds the set point value, the ECU checks to see whether the S/CE alarm detection circuit has generated an alarm signal. When the ECU has determined that the alarm detection circuit has failed, it will generate an alarm override signal. This signal is sent to the PLCC and PACC alarm control logic, which sets the alarm and bypasses the defective circuitry.

Some monitored propulsion plant parameters require a time delay. This is to prevent nuisance alarming of selected pressures and liquid levels. This is done by time delay electronic circuitry. This device has the capability of hardwire programming of the amount of time delay needed. The range of selectable time delay available on each circuit is 0.0 to 7.0 seconds in 0.5-second increments. Longer time delays can be provided by interconnecting more than one circuit. This circuitry can be compared to a countdown timer. If a 5-second time delay is programmed and it receives an alarm condition from the alarm

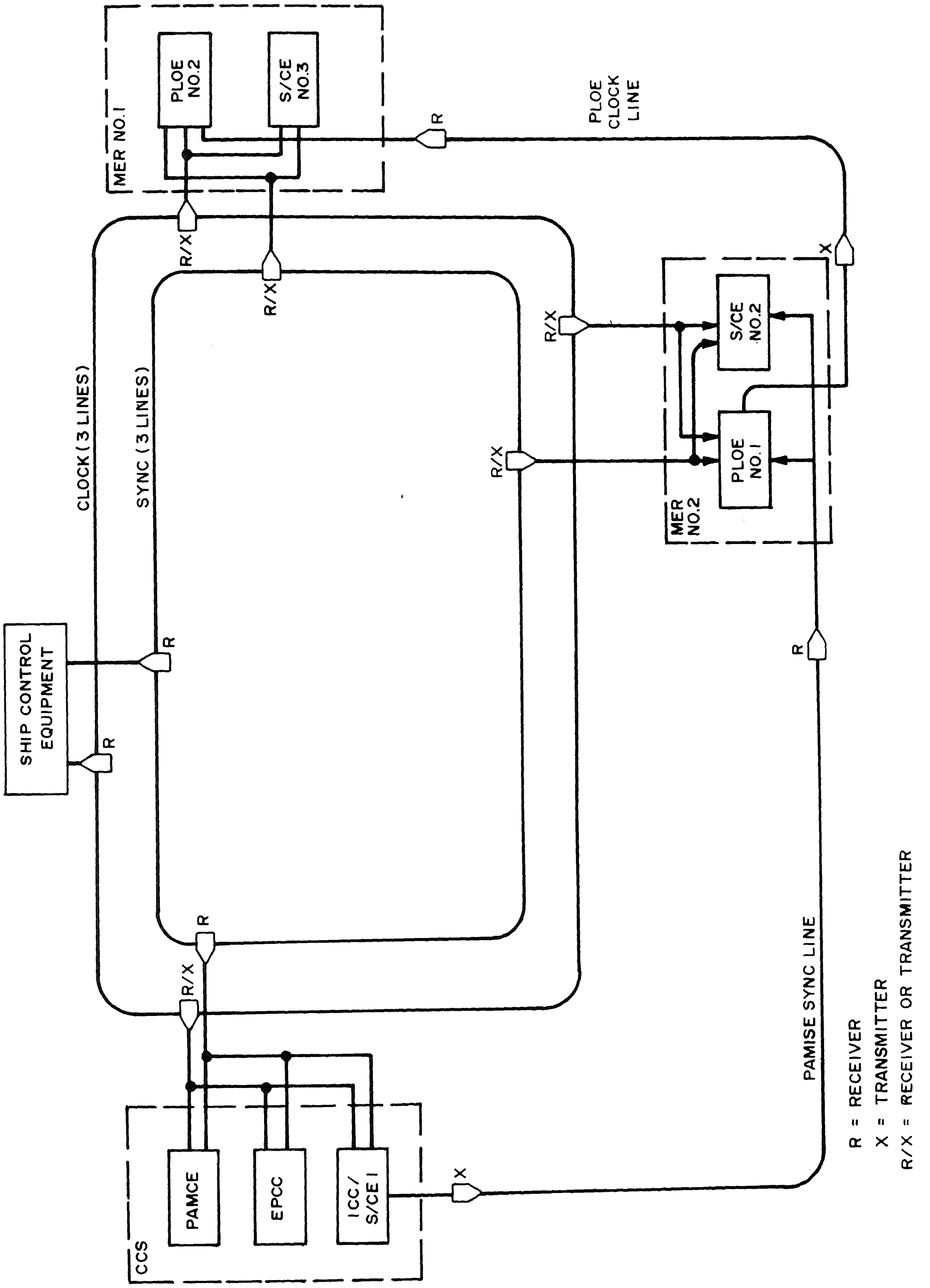

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Figure 9-35.—Clock and synchronization signal distribution.

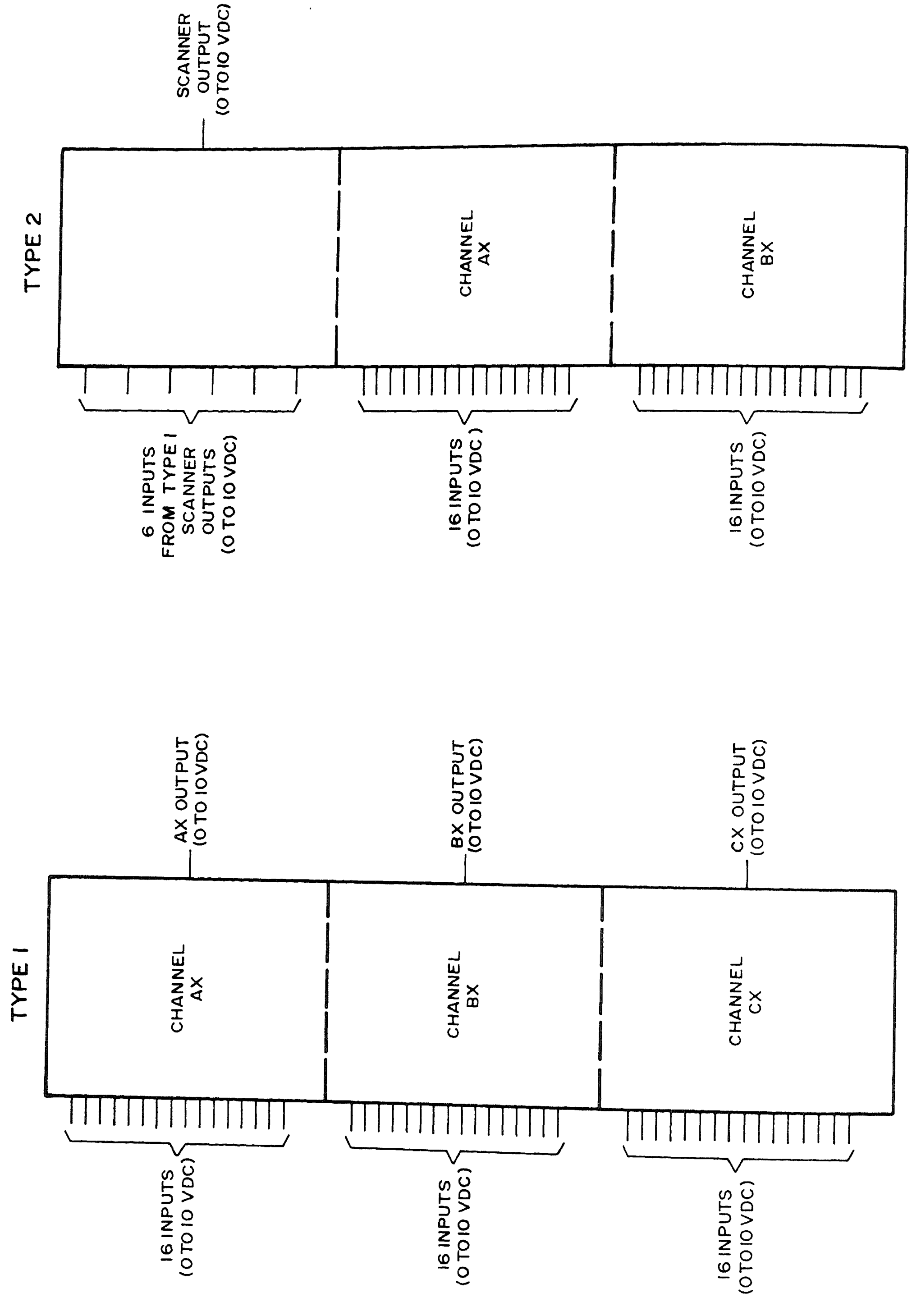

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Figure 9-36.—Analog scanners.

detector, the timer will be released and count to zero. At a count of zero, the alarm condition is sounded. Time delay circuitry includes digital filtering. This prevents electrical noise (negative going signals of less than 3 or 6 milliseconds duration) on the input from the alarm detector line from resetting the alarm time delay count-down (back to 5 seconds using the example above). Without this filtering, the noise could either cause a longer time delay or cancellation of the alarm. The ECU serves as a backup system. It generates the alarm if the alarm time delay circuitry fails.

Scanning and A/D Conversion

For the ECU to obtain its information, the parameters monitored by the S/CEs must be scanned one at a time. Then the information must be converted from an analog voltage value (0 to 10 volts) to a binary digital number (0 to 100 counts). This digital information is then serially transmitted from each S/CE to the ECU for storage in memory.

Scanning is performed at two levels called primary and secondary scanning. Scanning is performed by electronic circuitry called analog scanners. Two types of scanners are used. A block diagram of the Type 1 scanner used for primary and secondary scanning is shown in figure 9-36. The Type 2 scanner used for primary scanning is also shown in figure 9-36.

The Type 1 scanner has three channels with 16 inputs per channel and 1 output per channel. The inputs of the scanners are connected to the outputs of signal conditioner sensory signals (0 to 10 volts d.c.). By control timing pulses generated by the system clock (not shown in the figure), the scanners select 1 of 16 inputs of each AX, BX, or CX channel. That selected input is presented at the output of the channel being presently scanned.

The Type 2 scanner has two channels with 16 inputs per channel. It also has inputs from the outputs of a Type 1 scanner. The Type 2 scanner only has one output. Control timing pulses from the system clock are again used to present a selected input at the output of the Type 2 scanner.

In S/CEs No. 2 and No. 3 scanning is performed on the primary and secondary levels. Three Type 1 scanners and one Type 2 scanner are used (figure 9-37). Primary scanning has channels A1, B1, C1, A2, B2, C2, A3, and B3, with 16 inputs per channel. As each channel is enabled, each of the 16 respective channel inputs is sequentially connected to the output of the scanning system for 7.8 milliseconds. It takes 1 second to scan primary channels A1 through B3. The order of primary scanning is: A3-B3-A1-B1-C1-C2-B2-A2. During primary scan of channel A1, the first three inputs are the scanner outputs of channels A, B, and C in the secondary scanner. During a 1-second period of primary scan, only one input of each of the A, B, and C channels is presented to channel A1. During the next 1-second period of primary scan, the next respective input of each of the A, B, and C channels in the secondary scanner is presented to channel A1. Therefore, the main difference between primary and secondary scanning is that during a 1-second period all the inputs in the primary scanner are monitored; but, only 3 out of 48 inputs in the secondary scanner are monitored during the same 1-second sampling period.

In S/CE No. 1 scanning is done only on the primary level. Two Type 1 scanners and one Type 2 scanner are used (figure 9-36). A block diagram would be represented by deleting the secondary scanner shown in figure 9-37. Then replace the secondary scanner inputs on channel A1 with outputs from signal conditioners. The functional operation of this scanner is the same as discussed for the primary scanner for S/CEs No. 2 and No. 3.

From the outputs of the scanner, the analog voltage (0 to 10 volts d.c.) 7.8-millisecond samplings are passed to an A/D converter. During the 7.8-millisecond period, the A/D electronics converts the analog voltage to an equivalent binary number on a decimal scale of 0 to 1000 counts. For example, if a voltage of 5.47 is presented to the A/D converter electronics, it will output a binary value equal to 547 counts

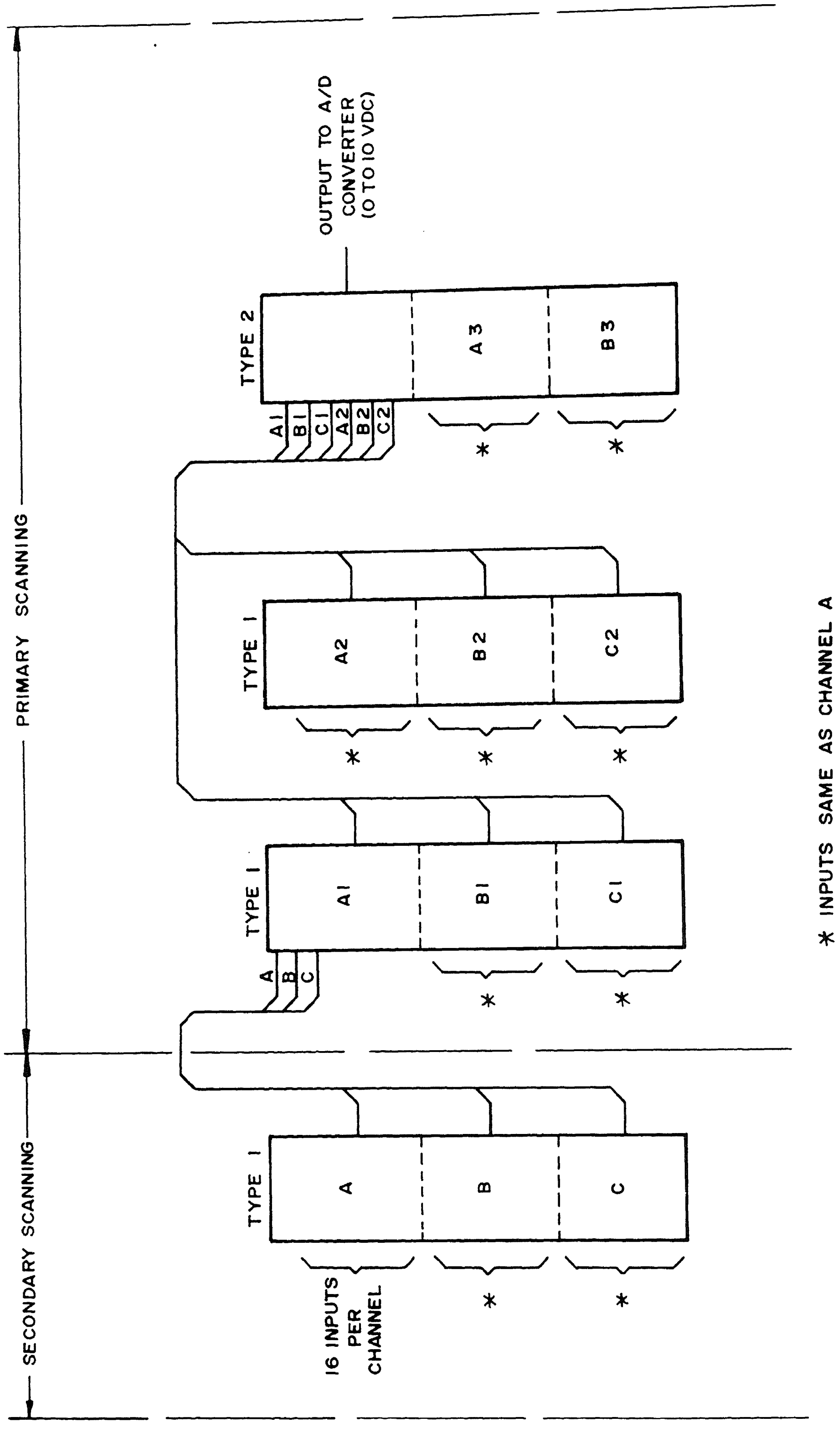

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Figure 9-37.—S/CEs 2 and 3 primary and secondary scanning.

(decimal) on ten weighted bit outputs; these are shown in table 9-2.

Using the above value of 5.47 volts d.c. into the A/D converter, the output is represented by the 1s and 0s above the input line. The binary number output is 1000100011 base 2. This is equal to 547 decimal.

The digital values are then sent to the ECU at the 7.8-millisecond rate over two separate serial data buses. One bus is used for S/CE No. 2 and the other for S/CE No. 3. Since S/CE No. 1 is located in the same enclosure as the ECU, serial transmission of the ten weighted bits is not required; instead, parallel format transmission is used. The serial transmission buses mentioned above are separate from the demand display and the command and control serial data systems. Transmission of information over this serial bus is similar to the method discussed earlier. An exception is that a maximum of 128 words is sent in a 1-second period from the S/CEs No. 2 and No. 3.

To review, remember that most sensory inputs, but not all, enter the S/CEs where they are signal conditioned (converted to a 0- to 10-volt d.c. signal). In the S/CEs, if these parameters have an alarm limit, they are alarm compared. If a parameter changes alarm state, an alarm signal is generated. It is sent to the ECU by a serial data bus dedicated only to alarm changes. The ECU then generates an alarm log. The S/CEs also hardwire this alarm change signal to the proper PLCC, EPCC, or auxiliary section of the PACC. This causes the proper indicator to change state and activates the horn or siren. The PACC receives the alarms from the PLCC via the command and control data bus, except for most of the auxiliary panel alarms. Finally, the S/CEs take the conditioned signals and convert them to digital values by A/D converters. These digital values are sent to the ECU by another serial data bus that does this job only.

OUTPUT CONTROL INTERFACE

So far we have discussed how the ECSS gathers information and how the consoles of the ECSS communicate. This section will analyze how the ECSS communicates commands to the engineering plant equipment. This communication is mainly done by the PLCC in one of three basic types of output depending upon the equipment to be controlled. The PACC controls the auxiliaries directly and not through the PLCC. The three basic types of control output are continuity, logic level, and power output.

1. Continuity—provides a contact closure or opening to be used by the external equipment. An example of this is the main fuel valve check switches. They provide an open/close command signal from the PLCC to the FSEE.
2. Logic level—provides a logic voltage level output, either on or off, to be used by the external equipment. An example of this is the battle override signal from the PLCC to the FSEE.

Table 9-2.—Sample A/D Conversion

Binary No.	1	0	0	0	1	0	0	0	1	1
Output Line	*	*	*	*	*	*	*	*	*	*
Equivalent Binary Weight	512	256	128	64	32	16	8	4	2	1
Demand Value Total 547	512		+		32		+		2 +	1

Note: Asterisk represents output conductors of A/D converter.

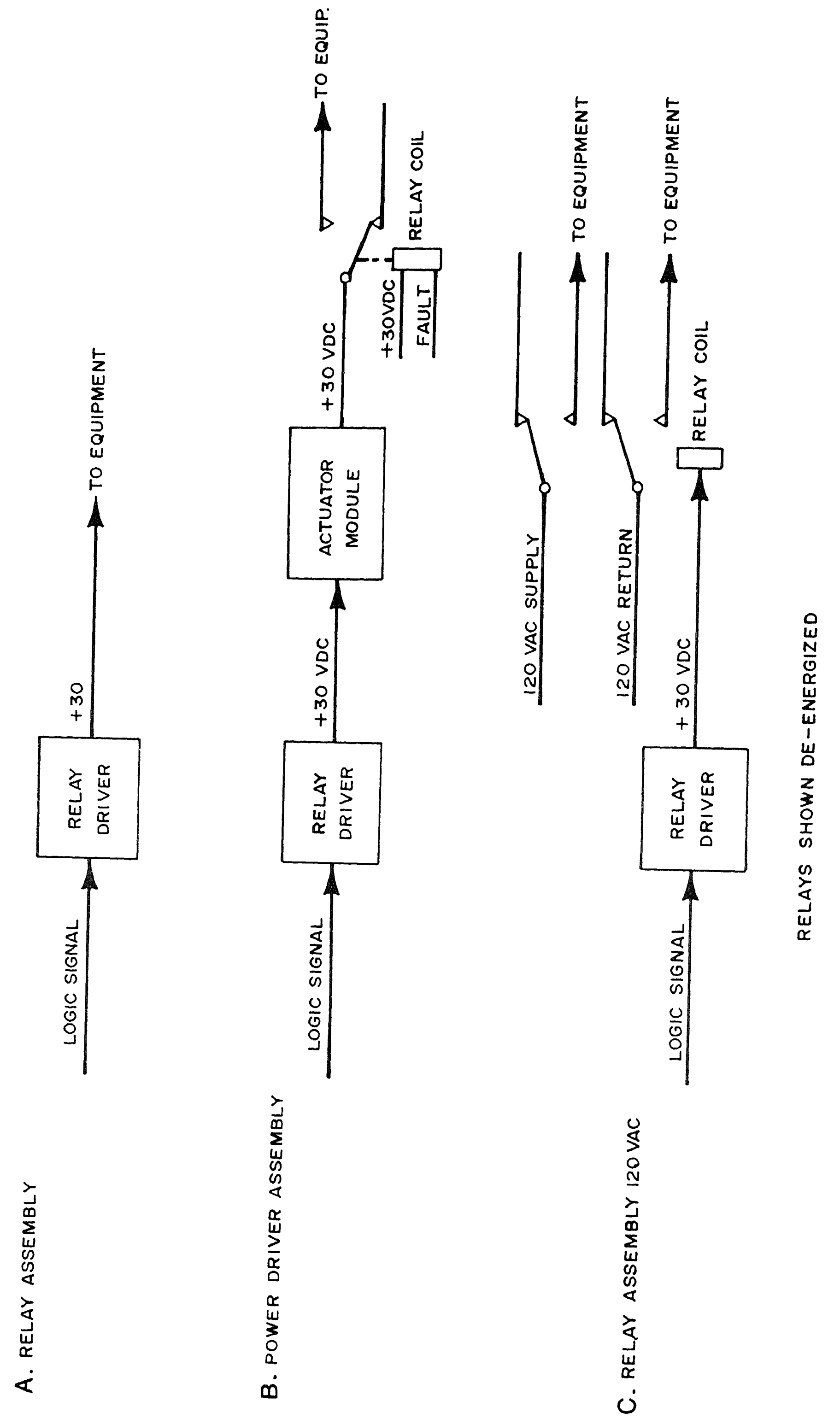

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Figure 9-38.—Power output signals.

3. Power output—provides a control voltage from the ECSS to the external equipment to be controlled. The power output signals are further subdivided into three types (actuator/relay driver, actuator module, and 120-volt a.c. relay driver assembly) as shown in figure 9-38.

a. The actuator/relay driver converts a logic level command to a 30-volt d.c. output. This type of control is used in the IR suppression circuitry at the PACC.

b. The actuator module takes the 30-volt d.c. signal from the actuator/relay driver. In effect, it amplifies it to provide a 30-volt d.c. output with greater current capability. This type of control is used for clutch/brake commands from the PLCC.

c. The 120-volt a.c. relay driver assembly converts a logic level command to 120-volt a.c. output. It uses a relay driver to energize a relay which provides the output. This type of control provides power to the igniters on the GTM.

FUEL SYSTEM CONTROL EQUIPMENT

The fuel system control equipment is not connected to any components of the ECSS. It is, however, an important electronic control console on the *Spruance* class ships; therefore, it is discussed in this chapter as is the damage control console.

The major components of this system include the FSCC, two FO local control panels, and the JP-5 local control panel. These four components are designated by unit numbers for circuit and part identification: FSCC—unit one, JP-5 local control panel—unit two, FO local panel No. 1—unit 3, FO local panel No. 2—unit 4 (power supply 2PS1 is located in unit 2, power supply 3PS1 is located in unit 3). These consoles and panels are an integrated information and control system. They provide operator control and monitoring from local and remote locations. In most cases, information generated by one unit of its system is shared by one or more of the other units. Fuel oil control uses the upper operator's panel of the FSCC and the FO local control panels; JP-5 control uses the lower operator's panel of the FSCC and the JP-5 local control panel.

FUEL SYSTEM CONTROL CONSOLE

The FSCC has three main cabinet assemblies (A1, A2, A3), the fuel oil fill and transfer control panel (A4), and the JP-5 control panel (A5). Figure 9-39 shows the console outline and component location. The three main cabinet assemblies contain the power supplies, electronic hardware, and internal wiring of the FSCC. The fuel oil fill and transfer control panel A4 has the operator controls and indicators for the FO fill and transfer system. The JP-5 control panel A5 has operator controls and indicators for the JP-5 fill, transfer, and service systems.

Power Supplies

The FSCC has eight power supplies located in the power supply drawers. Two supplies are used for each voltage level. They normally operate in parallel, sharing the current load. The LEDs at the power supplies show voltage output. If one supply of a pair should fail, the LED for that supply will extinguish. The other power supply of the pair will automatically supply the load. Isolation diodes between the power supplies prevent the failed supply from absorbing current. Each power supply has an output voltage adjust potentiometer (R1) to calibrate the supply within its specified tolerance.

The FSCC sends +24 volts d.c. power to all three local panels for illumination of indicators controlled by the FSCC. The FSCC also receives +24 volts d.c. power from the three local control panels to operate indicators energized by the local panels.

Card Cage

Section 1A2A1 houses the card cage. It has the 32 printed circuit boards (PCBs) used in

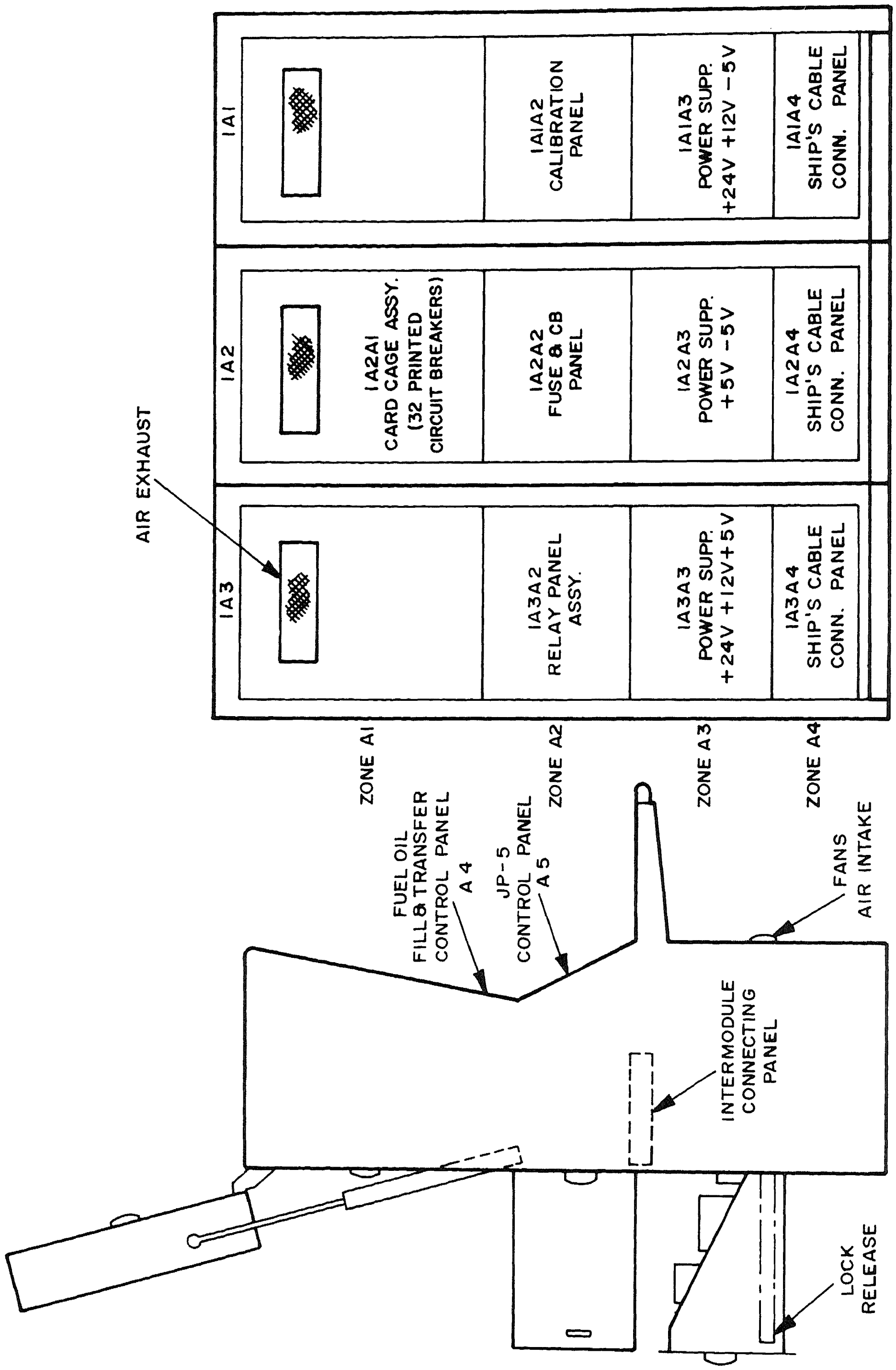

Figure 9-39.—Fuel system control console—component location.

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monitoring, alarm, and control functions. The card cage assembly will swing up for maintenance. The function of particular card types is discussed later in this section.

Circuit Breaker Panel

Section 1A2A2 of the FSCC has the fuse and CB panel. CB1 is the main power CB for the FSCC. Fuses 1 through 10 protect the console from faults in the 120-volt a.c. remote control wiring. The three switches, S1, S2, and S3, turn power on/off to the three power supply drawers.

Relay Panel Assembly

Section 1A3A2 of the FSCC has the relay panel assembly. The nine 24-volt d.c. relays control FO and JP-5 valve closing. They are energized by the auto fill circuits. Associated with each relay is a suppression diode (CR1 through CR9) to prevent damage to the auto fill logic output circuits. The front side of this panel holds the spare fuses for the console.

Calibrate Panel

Section 1A1A2 of the FSCC has the calibrate panel. This panel has the switches and potentiometer used in calibrating meter circuits and setting alarm points for those functions processed by the FSCC.

Storage tank level meter calibration is done using a three-position momentary contact switch, a full scale adjust potentiometer, and the associated zero adjust potentiometer for each tank. If the switch is pushed to the FULL position, you can set the full adjust potentiometer to obtain a full scale reading on the associated panel meter. When the switch is in the ZERO position, you can set the zero adjust potentiometer to obtain a zero panel meter reading.

You can also calibrate the FO receiving tank pressure meter circuits at this panel. A PUSH TO ADJUST FULL SCALE pushbutton is associated with each receiving tank pressure circuit. When the pushbutton is depressed, you can set the panel meter for full scale by adjusting the full scale adjust screw on the panel meter assembly.

From the calibration panel, you can adjust the high seawater, fuel overflow, JP-5 storage tank level HI/LO, and FO receiving tank pressure high hazard alarm set points. When the pushbutton for one of these alarms is depressed, the associated panel meter reads the alarm set point. By turning the corresponding adjust potentiometer, you can adjust the alarm set point to its desired value.

Also located on this panel are two mode switches. These affect the JP-5 storage tank circuits. When in the LOCAL ONLY position, only the FSCC panel meter indicates tank level. When in the LOCAL AND REMOTE position, both the FSCC and the JP-5 local control panel meters function.

Operator's Panels

The upper console operator's panel is used to monitor and control the FO fill and transfer systems. The lower panel contains monitor and control functions for the JP-5 system. These panels have mimics of the associated system, vertical reading meters to display system parameters, indicator lights to display system status, and pushbuttons to remotely control motor-operated equipment.

FUEL OIL LOCAL CONTROL PANELS

The two FO local control panels are similar. The FO local control panel No. 1 has control and monitor equipment for the No. 1 FO transfer equipment; FO local control panel No. 2 has control monitor equipment for the No. 2 transfer equipment. Information is exchanged between each of the local panels and the FSCC.

These panels are bulkhead mounted. They have an upper and lower front panel and a metal enclosure that houses the power supplies and

electronic circuits. Figure 9-40 is an outline of the FO local control panel.

Power Supplies

Each FO local control panel has four power supplies, one for each d.c. voltage level used (+5 V, −5 V, +12 V, +24 V). The local +5 volt, −5 volt, and +12 volt supplies are the same type as those in the FSCC. The 24-volt supply used in the local panels is functionally similar to the FSCC 24-volt supply; however, the maximum power output is less. Each power supply voltage is adjustable. Each local panel sends 24 volts d.c. power to the FSCC. This is used to illuminate remote indicators controlled by the local panel.

Card Cage

The card cage, mounted on a hinged panel with the calibrate panel, houses the 13 PCBs for each FO local control panel. These cards are used for monitor and control functions.

Power Distribution Panel

Each FO local control panel assembly houses a power distribution panel. This panel has the

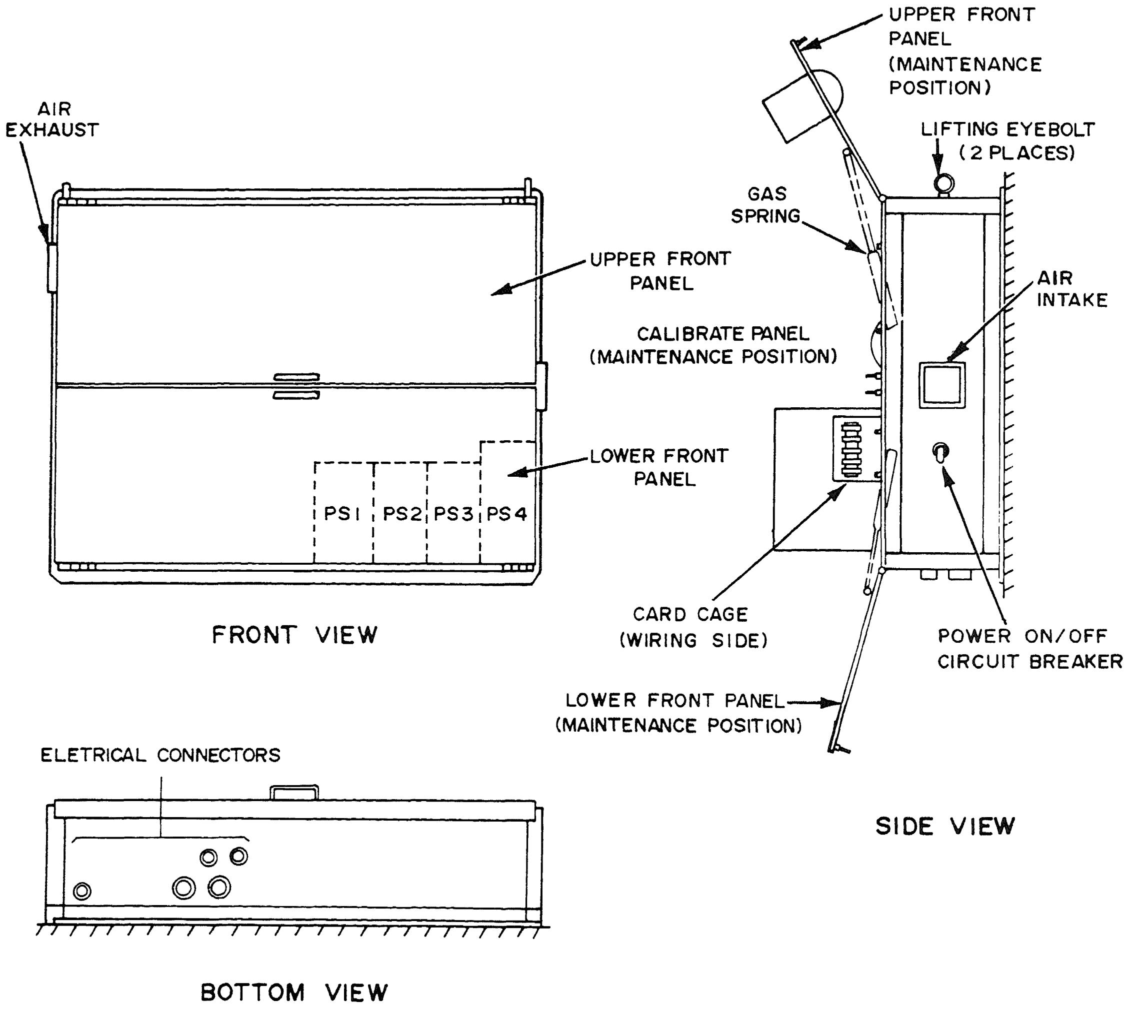

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Figure 9-40.—Fuel oil and JP-5 local control panels—component location.

terminal boards for panel connections and the protective fuses for that particular panel.

Power to a local panel is controlled by one a.c. CB, CB1. This CB is located on the right side of the enclosure (figure 9-40).

Calibrate Panel

Each FO local control panel has a calibrate panel. It serves the monitor and alarm circuits of the local panel in the same manner that the FSCC calibrate panel serves the FSCC circuits. The panel is used to calibrate associated service tank level, transfer pump pressure, FO heater temperature, and purifier pressure meter circuits. You can also set service tank level HI/LO alarms, transfer pump pressure alarms, and purifier discharge pressure alarm set points at this panel. All seven meter circuits have mode switches for selection of LOCAL AND REMOTE or LOCAL ONLY displays.

Operator's Panel

The upper front panel of each FO local control panel has the meters, indicators, and pushbuttons necessary to operate the transfer system. The panel is arranged as a mimic of the particular transfer system it controls.

JP-5 LOCAL CONTROL PANEL

The JP-5 local control panel is similar in construction to the FO local control panels. The monitoring and control functions of this panel are for the JP-5 fill, transfer, and service systems. This panel exchanges information with the FSCC only.

Power Supplies

The JP-5 local control panel has four power supplies, one for each d.c. voltage level used (+5 V, −5 V, +12 V, +24 V). The arrangement of these power supplies in the enclosure is similar to the FO local control panel arrangement. Twenty-four volts is sent to the FSCC for illumination of indicators controlled by the local panel. All four power supplies are energized by the CB1.

Card Cage

The card cage, mounted on a hinged panel common with the calibrate panel, houses the 12 PCBs used for control and monitor functions.

Power Distribution Panel

The JP-5 local control panel has a power distribution panel. It is similar to those in the FO local control panels.

Calibrate Panel

The calibrate panel of the JP-5 local control panel is similar in function to those in the FSCC and FO local control panels. The only circuits serviced by this panel are the JP-5 service tank level high and low alarm functions. No mode switches are on this panel. This is because the only JP-5 service tank level meters are at the JP-5 local control panel.

Operator's Panel

The upper front panel of the JP-5 local control panel has the meters, gauges, indicators, and pushbuttons necessary to operate the JP-5 fill, transfer, and service systems. This panel is the primary control center for JP-5 transfer and service operations. This is because the FSCC only has provisions for limited monitoring and terminating of these operations.

All pressure monitoring at the JP-5 local control panel is done with pressure gauges. At the top of the enclosure are gauge cutout valves for each of the gauges.

TANK LEVEL MONITORING AND ALARM

The FO fill and transfer control system measures levels in each of 24 FO storage tanks, 4 FO service tanks, 2 JP-5 storage tanks, and 2 JP-5 service tanks. Individual tank levels are displayed by vertical panel meters at the FSCC, the JP-5 local control panel, and the FO local control panels. All tank level circuits function in a similar manner. They convert analog information from a tank level transmitter to a meter display. Also, some of the circuits have associated hazard alarms for high- or low-level conditions.

These electronic circuits are located either at the FSCC or one of the local panels, depending

Table 9-3.—Tank Level Monitoring Circuit Locations

TANK TYPE	CIRCUIT LOCATION	HAZARD ALARM	REMOTE DISPLAY
FO Storage, Receiving	FSCC	High Seawater	None
FO Storage, Mid Position	FSCC	None	None
FO Storage, Last Position	FSCC	Fuel Overflow	None
FO Service, Fwd	*FOLP 1	High, Low	FSCC, FOLP 2
FO Service, Aft	*FOLP 2	High, Low	FSCC, FOLP 1
JP-5 Storage	FSCC	High, Low	JP-5 Local
JP-5 Service	JP-5 Local	High, Low	FSCC (alarm only)

*FOLP Fuel Oil Local Control Panel

upon the particular level function. Table 9-3 is a list of the types of level measuring circuits, their locations, associated hazard alarms, and remote displays.

Tank Level Transmitters

Each of the level monitored tanks has a level transmitter. A typical transmitter section has a voltage divider resistor network extending the length of the section. Magnetic reed switches are tapped at 1-inch intervals along the resistor network. The reed switches are sequentially connected through series resistors to a common conductor. This network is enclosed in a stem that is mounted vertically in the tank. A float with bar magnets rides up and down the stem as the level changes.

In operation, a calibrated voltage is supplied to the ends of the divider network from an external source (the FSCC or a local panel). As the float moves up or down the stem, the reed switches are closed in a two-at-a-time, three-at-a-time, two-at-a-time sequence. When two switches are closed, the effective tap point is halfway between the two switches. When three switches are closed, the effective tap point is at the middle of the three. As a result, the effective tap point changes in half-inch increments. The common conductor voltage is, therefore, proportional to the float level within a half-inch of travel. This voltage provides tank level information to the system.

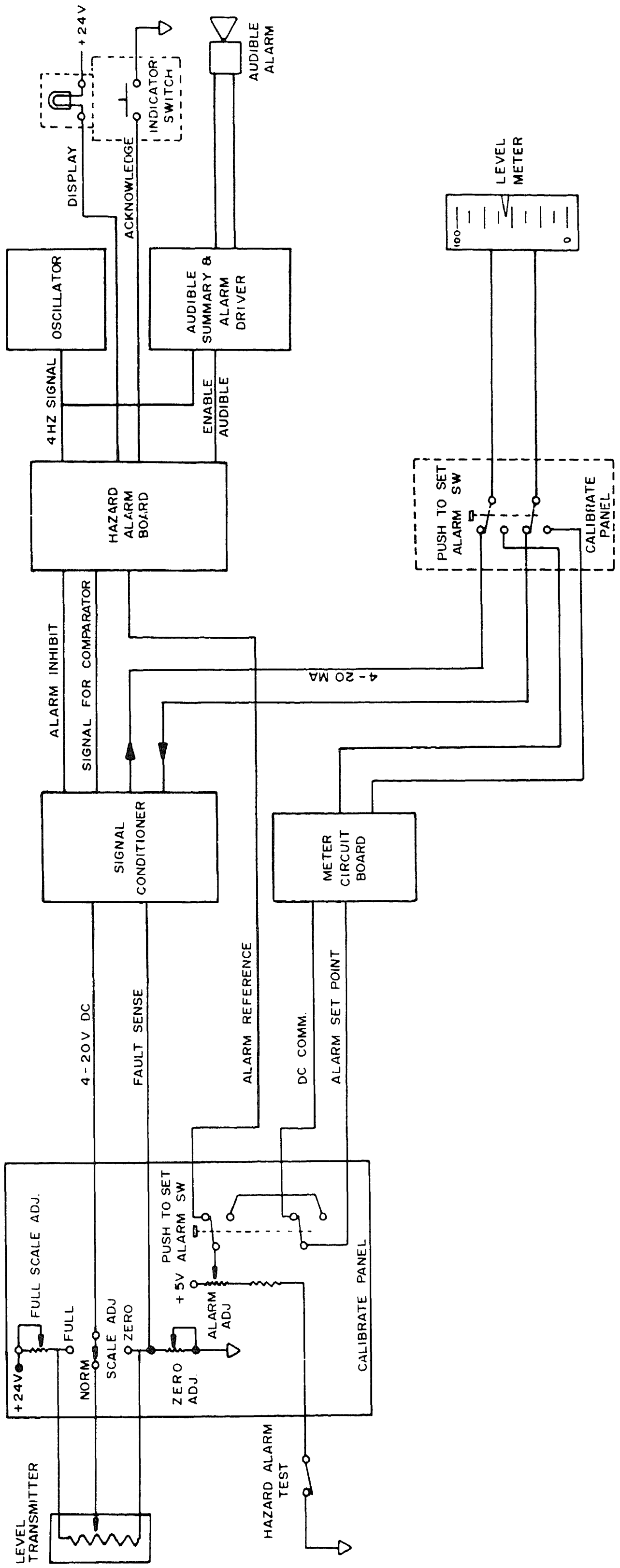
The physical arrangement of many tanks necessitates the use of more than one transmitter section to measure the full range. When multiple sections are used, they are electrically connected as one continuous divider network.

Two types of floats are used. In noncompensated tanks, the float is designed to float at the surface of the FO or JP-5. For seawater compensated tanks, the float is designed to stay at the seawater/FO interface.

Service and Storage Tank Level Monitoring Circuits

The signal from the level transmitter is sent to a level monitoring circuit in either the FSCC, FO local panel No. 1 or No. 2, or the JP-5 local control panel, depending upon the particular tank (see table 9-3). This circuit, in turn, drives the associated panel meter(s), starts the visual and audible indications for a hazard alarm, provides sensor circuit fault indication, and provides the meter and alarm calibration. The following paragraphs describe a typical tank level monitoring circuit (figure 9-41).

NORMAL METER DISPLAY.—The calibrate panel provides the voltage for the level transmitter voltage divider network. The voltage level is about 4 volts at one end and 20 volts at the other. These voltages are adjustable. They are set using the SCALE ADJUST switch to give zero and full meter readings corresponding to switch position. Adjustments are made using the FULL SCALE ADJUST and ZERO ADJUST potentiometers. This is done while the switch is held in the FULL or ZERO position accordingly.



293.70

Figure 9-41.—Typical tank level monitoring circuit.

The third transmitter wire provides a voltage signal that corresponds to tank level. When the float is at the bottom of the divider assembly, the level signal is at the 4-volt level. It is at the 20-volt level when the float is at the top. Thus, the level ranges from 4 volts for an empty tank to 20 volts for a full tank. This 4- to 20-volt d.c. signal goes to the signal conditioner. One output of the signal conditioner is a 4- to 20-mA signal. It is proportional to the 4- to 20-volt d.c. level input that goes to the panel meter.

For tank level circuits with more than one meter, a mode switch on the calibrate panel will send the 4- to 20-mA signal to both local and remote meters in one position. The mode switch also limits the signal path to only the local meter when in the other position.

HAZARD ALARM.—Another output of the signal conditioner serves as a level signal for the hazard alarm board. The hazard alarm board compares this signal to an alarm reference signal. If the level signal drops below the alarm reference, the hazard alarm board outputs an audible enable signal to the audible summary and alarm driver. This driver energizes the audible alarm at a 4-Hz rate. At the same time, the hazard alarm board flashes the indicator light at a 4-Hz rate. Depressing the pushbutton indicator provides an acknowledge signal to the hazard alarm board. This de-energizes the audible alarm. Then the indicator light illuminates steadily. If the level signal into the hazard alarm board raises back above the alarm reference, the indicator light extinguishes.

For tank level circuits with remote alarm indicators, the display signal is sent to the remote indicator. The enable audible signal is sent to the audible summary and alarm driver of the remote panel to energize the remote audible alarm. The remote acknowledge signal is fed back to the hazard alarm board for remote acknowledgement of the alarm.

Depressing the HAZARD ALARM TEST pushbutton opens the return for the alarm reference. This causes this signal to go high. The hazard alarm board, therefore, senses a hazard alarm condition and begins the 4-Hz audible and flashing light indications. The alarm must be acknowledged to silence the audible alarm and steady the indicator light. Releasing the HAZARD ALARM TEST pushbutton removes the alarm test.

When the PUSH TO SET ALARM switch is depressed, the alarm reference signal is routed to a meter circuit board. Here it is converted to a current signal. The PUSH TO SET ALARM switch at the same time connects the meter to the meter circuit board output. The meter reads the alarm threshold setting directly.

Both high- and low-level hazard alarms are used in the system. They function in a similar manner. For a high-level alarm, the alarm reference network is reversed. Depressing the HAZARD ALARM TEST causes the alarm reference to go low.

FAULT CONDITIONS.—The level meter circuits are designed with elevated zero readings. A meter signal of about 4 mA is required to deflect the needle to the zero scale reading. If no meter current is supplied, the needle reads below scale.

If a level transmitter circuit opens, current stops flowing. The fault sense signal from zero adjust resistor goes to common. When the signal conditioner detects this change, it drives the meter current to zero and inhibits the hazard alarm. The operator is alerted to a transmitter circuit fault only by a below scale indication on the meter.

Drain Tank Level Monitoring

The FO purifier drain tanks are monitored for an 80% FULL or 95% FULL condition (figure 9-42). The JP-5 drain tank is monitored for a 95% FULL condition.

LEVEL SENSORS.—The level sensors for the drain tank are single station float switches. The float switches are positioned in the tanks at the level corresponding to their function. The 95% FULL switches have a terminal resistor used in fault sensing.

80% LEVEL INDICATORS.—The 80% FULL circuits have a float switch, an indicator light, and a 24-volt d.c. power input. When the float switch closes, the indicator light illuminates. No alarms are associated with this circuit.

95% FULL HAZARD ALARMS.—When the 95% FULL float switch contacts close, a 24-volt d.c., 95% FULL alarm signal is sent to the fault and hazard alarm board. This board will output a fault alarm signal to the audible summary and alarm driver. The 95% FULL

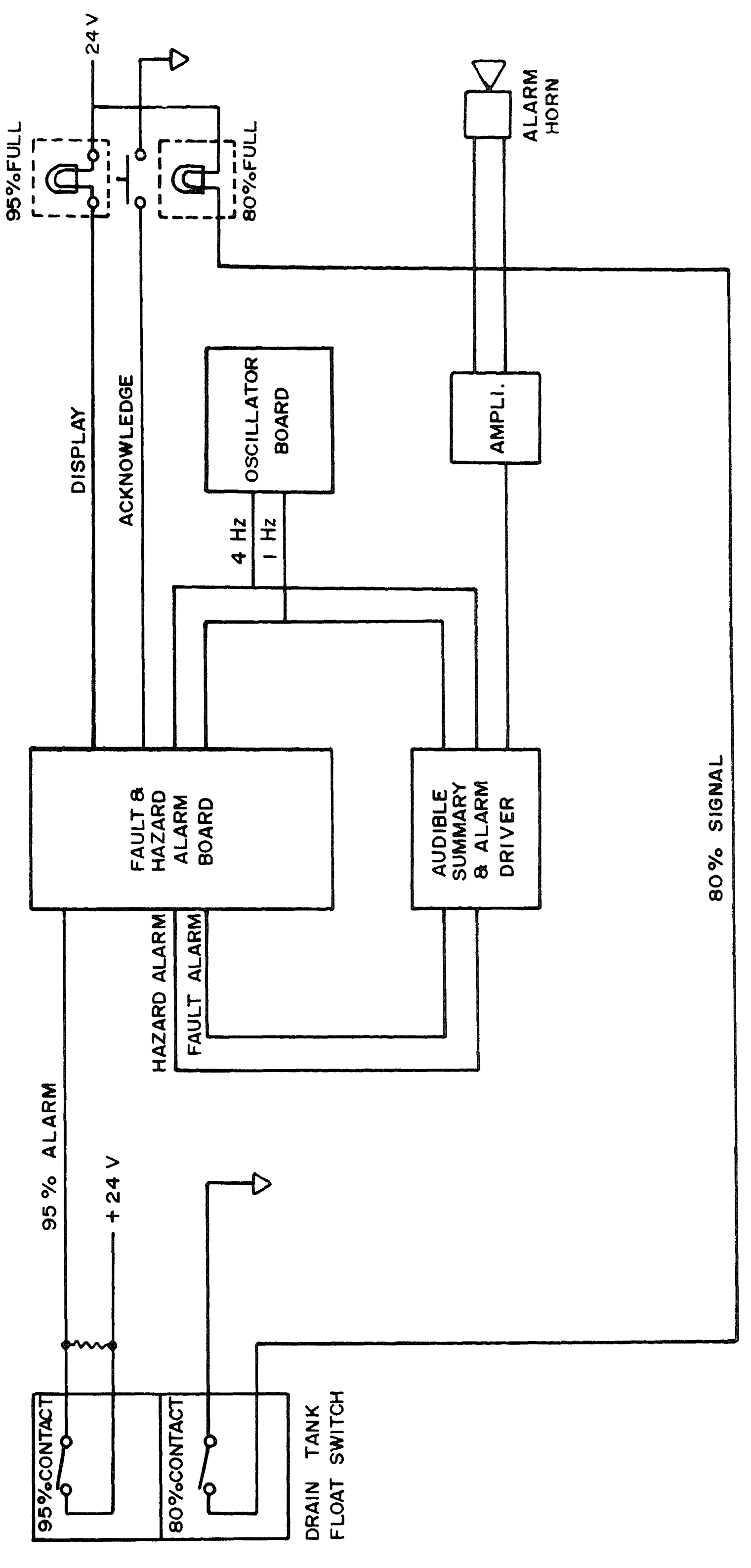


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Figure 9-42.—Fuel oil drain tank level monitoring circuit.

Table 9-4.—Pressure Monitoring Circuit Locations

CIRCUIT FUNCTION	CIRCUIT LOCATION	HAZARD ALARM	REMOTE DISPLAY
FO Receiving Tank	FSCC	High Pressure	None
FO Transfer Pump Inlets	*FOLP 1,2	High Pressure	FSCC
FO Transfer Pump Discharges	*FOLP 1,2	High Pressure	FSCC
FO Purifier Inlets	*FOLP 1,2	None	FSCC
FO Purifier Discharges	*FOLP 1,2	High Pressure	FSCC

*FOLP - Fuel Oil Local Control Panel

indicator will flash at the 4-Hz rate. The audible summary and alarm driver energizes the amplifier and speaker (for local panels) at the 4-Hz rate. Acknowledgement of the alarm will de-energize the amplifier and cause the indicator light to illuminate steady. When the 95% FULL contact opens, the indicator light extinguishes.

FAULT ALARMS.—Unlike the service and storage tank level monitoring circuits, the 90% FULL circuits show a sensor line fault with a fault alarm. Since the 95% FULL sensor circuits have terminal resistors at the tank junction box, a quiescent current flows in the sensor lines even when the contacts are open. If the sensor lines fault by opening, this current stops flowing. The fault and hazard alarm board senses this condition and starts a fault alarm. For this fault alarm, the indicator light illuminates at the 1-Hz rate. The audible circuit will be energized at the 1-Hz rate. The acknowledge signal from the pushbutton indicator de-energizes the audible but not the flashing indicator display. The only way to extinguish the light is to eliminate the fault condition. Depressing the FAULT TEST pushbutton sends a 5-volt d.c. fault alarm test signal to the hazard and fault alarm board. This will initiate a fault alarm. Figure 9-42 shows a simplified FO purifier drain tank monitoring circuit. The actual circuits include provisions for remote alarm display and acknowledgement. The JP-5 drain tank monitoring circuit is similar, except no 80% FULL circuit exists.

PRESSURE MONITORING AND ALARM GENERATION

Pressure is monitored and displayed for the FO receiving tanks, FO transfer pump inlets and discharges, and FO purifier inlets and discharges. All but the purifier inlets are provided with HIGH PRESS hazard alarms. These circuits are all functionally similar. Table 9-4 is a list of circuit locations and remote displays.

Pressure Transducers

The pressure tranducers used in these circuits are the same type used in the ECSS. These pressure transducers are supplied with system +24 volts d.c. They regulate current flow between this +24 volts and common. This current is regulated to be proportional to the pressure input. The current is varied from 4 to 20 mA as the pressure changes from the low extremity of its range to the maximum. Current regulation is accomplished by circuits located within the transducer.

Pressure Monitoring Circuits

The pressure signal from the pressure transducer is sent to a pressure monitoring circuit in either the FSCC or one of the FO local control panels, depending upon the particular parameter (table 9-4). This circuit provides meter calibration, starts hazard alarms, and provides alarm point adjustment. It also gives fault condition indication. The following paragraphs describe a typical pressure monitoring circuit (figure 9-43).

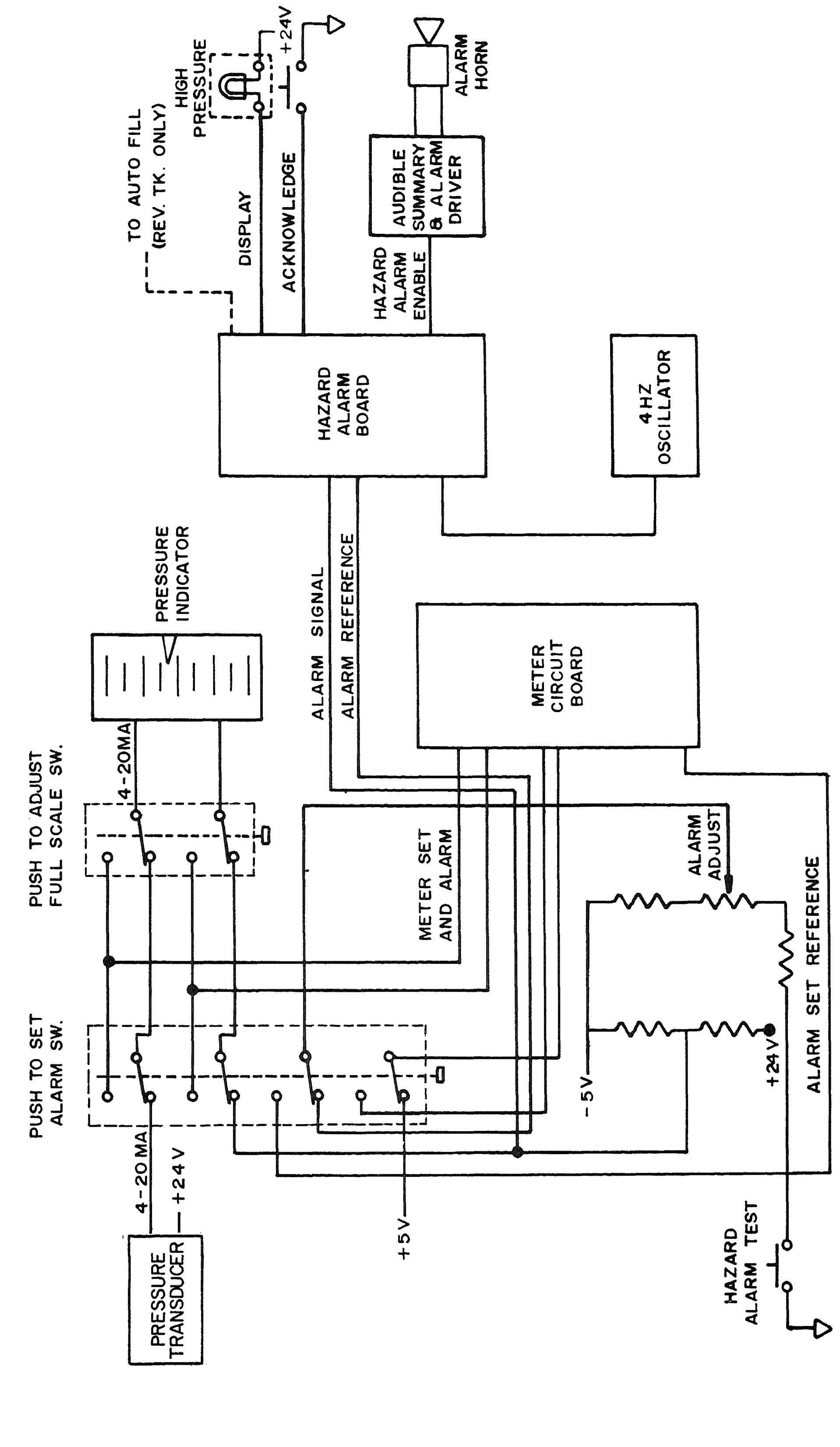

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Figure 9-43.—Typical pressure monitoring circuit.

NORMAL METER DISPLAY.—Since the pressure signal provided by the pressure transducer is a 4- to 20-mA current representing pressure, no signal conditioning is required. The signal is routed through the PUSH TO SET ALARM switch, the PUSH TO ADJUST FULL SCALE switch, and then through the panel meter (and remote meters if used). The return path is to −5 volts d.c. through a fixed resistor. This resistor provides a voltage signal proportional to pressure for alarm operation.

The PUSH TO ADJUST FULL SCALE switch is used to calibrate the meter full scale reading. When depressed, this switch disconnects the meter (or meters) from the transducer. It connects them to a 20-mA meter setting signal from the meter circuit board. The full scale setting is made at the meter's mechanical full scale adjustment screw.

When remote meters are used, a mode switch is used for selection of LOCAL AND REMOTE or LOCAL ONLY displays.

HAZARD ALARM.—The hazard alarm function is similar to that of the tank level monitoring circuits. The alarm signal for the hazard and alarm board is generated by the voltage drop across the fixed resistor in the meter current return path. The alarm reference is established by a voltage divider between −5 volts d.c. and common. Depressing the HAZARD ALARM TEST pushbutton opens the return for the alarm reference voltage divider. This causes the reference to go low and the hazard alarm to be started.

When the PUSH TO SET ALARM switch is depressed, the panel meter is again connected to the output of the meter circuit card. The meter circuit card is programmed to output a current signal proportional to the alarm reference voltage. Then meter displays the actual alarm set point. You can adjust it to the required value using the ALARM ADJUST potentiometer.

FAULT CONDITION.—An open circuit in the transducer circuit stops meter current flow. The meter displays a below scale reading during this fault condition with no fault alarm. No hazard alarm is started, as the hazard alarms are for high pressure.

JP-5 Filter/Separator Alarm Circuits

The JP-5 transfer and service filter/separators are monitored for high differential pressure. The sensors used are differential pressure switches, set to actuate at 15 psid. When the sensor contacts close, the associated filter/separator alarm circuit in the JP-5 local control panel will start a hazard alarm. These circuits are also provided with the 1-Hz fault alarm. Functionally, the filter/separator alarm circuits operate the same as the drain tank level 95 percent circuits.

FUEL OIL TEMPERATURE MONITORING

Temperature of the FO discharged from the two FO transfer heaters is monitored by the system. It is displayed at the associated FO local control panel and the FSCC (figure 9-44). The meter circuitry is located in the associated FO local control panel.

Temperature Sensors

The temperature of the FO is sensed by the RTDs, similar to the type used in the ECSS. Associated with each RTD is a signal conditioner. It uses system 24 volts d.c. to regulate a 4- to 20-mA output at a value proportional to the RTD resistance.

Temperature Monitoring Circuits

The monitoring circuit for FO heater No. 1 is located in FO transfer local panel No. 1; the No. 2 heater circuit is in local panel No. 2. Each circuit has a remote display at the FSCC.

Since the temperature signal from the signal conditioner is at a 4- to 20-mA level, it is routed through the PUSH TO SET FULL SCALE switch to the panel meters. A mode switch allows

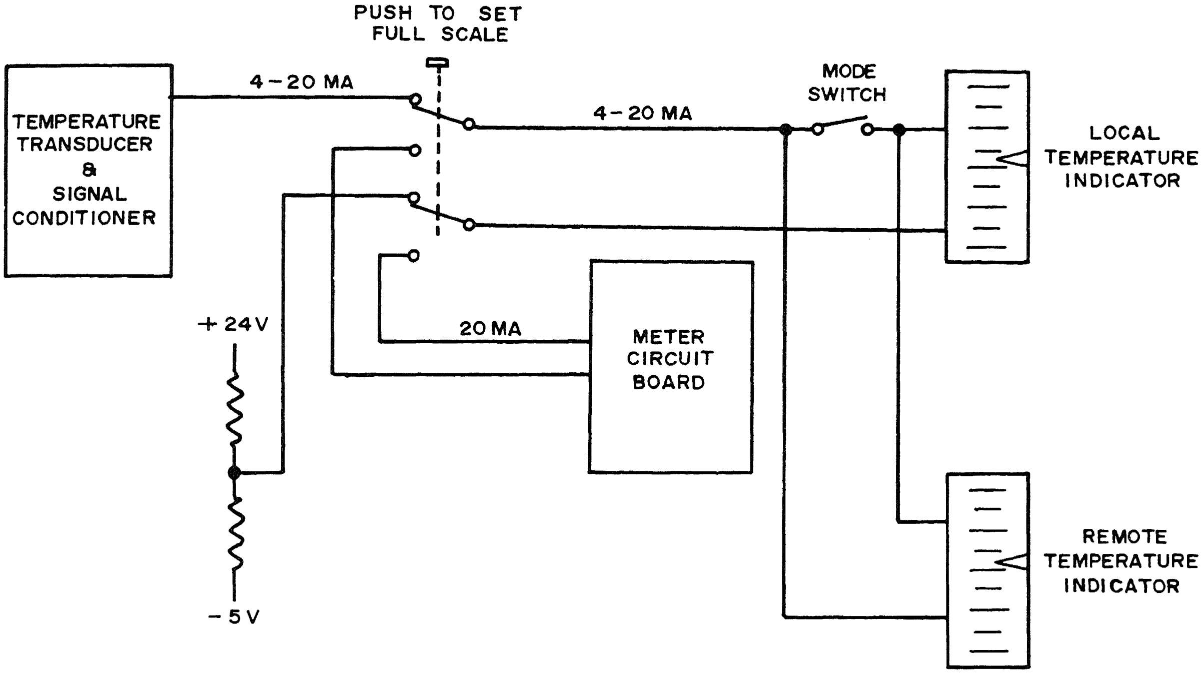

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Figure 9-44.—Temperature monitoring circuit.

selection of LOCAL AND REMOTE or LOCAL ONLY displays. The meter current return is through a fixed resistor to -5 volts.

When the PUSH TO SET FULL SCALE pushbutton is depressed, a 20-mA signal is routed from the meter circuit board to the meter. You can adjust full scale by using the mechanical full scale adjust screw on the meter.

REMOTE CONTROL OF EQUIPMENT

Remote control of selected valves, pumps, and purifiers is provided by pushbuttons at the FSCC and the local panels. The 120-volt a.c. control signals from the pushbuttons energize control relays in the associated motor controllers. Some automatic valve control is provided by the auto fill circuitry.

Pump and Purifier Control

Each of the pump and purifier motors has an associated motor controller. These controllers have selector switches. They enable only the controller pushbutton when in the LOCAL position and only the remote pushbuttons when in the REMOTE position.

If the selector switch is in the REMOTE position, depressing one of the remote ON pushbuttons energizes a run relay in the controller. This run relay picks up the main contactor and the motor will start. At the same time, an auxiliary contact on the main contactor closes, illuminating the ON light on the panel pushbutton indicator. Depressing one of the OFF pushbuttons picks up a stop relay in the controller. This de-energizes the main contactor. The auxiliary contacts extinguish the ON panel indicator lights, then the OFF panel lights illuminate.

Table 9-5 is a list of the pump and purifier remote controls available to the FSCC and the local panels.

Remote Valve Control

You can remotely control each motor-operated valve in the FO fill and transfer and JP-5 systems from the FSCC and/or one of the local panels. The motor-operated valves include the main fill valve, FO receiving tank cutout valves, fuel service tank fill valves, and JP-5 storage and service tank fill valves.

Associated with each motor valve operator is a controller with OPEN and CLOSE pushbuttons. Depressing the OPEN pushbutton picks up and latches the OPEN contactor. Then the motor turns the valve in the open direction. When the valve has reached the open position, a valve travel limit switch opens. The OPEN contactor will drop out. A second limit switch completes the circuit to the OPEN panel light on the controller. A third limit switch provides a CLOSE signal for remote indicators. Depressing the CLOSE pushbutton starts a similar sequence in the close direction.

Also, you can begin the open/close functions by energizing the open or close relay in the controller. These relays are controlled by the OPEN and CLOSE pushbutton indicator on the FSCC and/or local control panels.

The valve motor controllers provide protection for overtorque and overload conditions. If these conditions are reached, the control circuit is interrupted and the contactor de-energized.

The controller for the main fill valve allows partial opening and closing of the valve. The contactors do not latch in. The operator must maintain them by keeping the local or remote pushbutton depressed until the valve reaches the desired position. Valve travel limit switches function to prohibit travel beyond the full open/close position and to energize the OPEN/CLOSE indicator lights. You can also close the main fill valve by the auto fill circuitry.

MANUAL VALVE STATUS INDICATIONS

The primary manual valves used in FO transfer and recirculating operations are equipped with open and closed limit switches. These switches provide open/close signals to the associated FSCC and FO local control panel indicator lights when the valve is in the fully open or fully closed position.

The JP-5 control panel at the FSCC and the JP-5 local control panel also have some manual valve status indicator lights. These valves are not provided with limit switches. The operator must set the pushbutton indicator at the JP-5 local control panel to the proper status. This switch provides the open/close signal to the associated indicator at the FSCC.

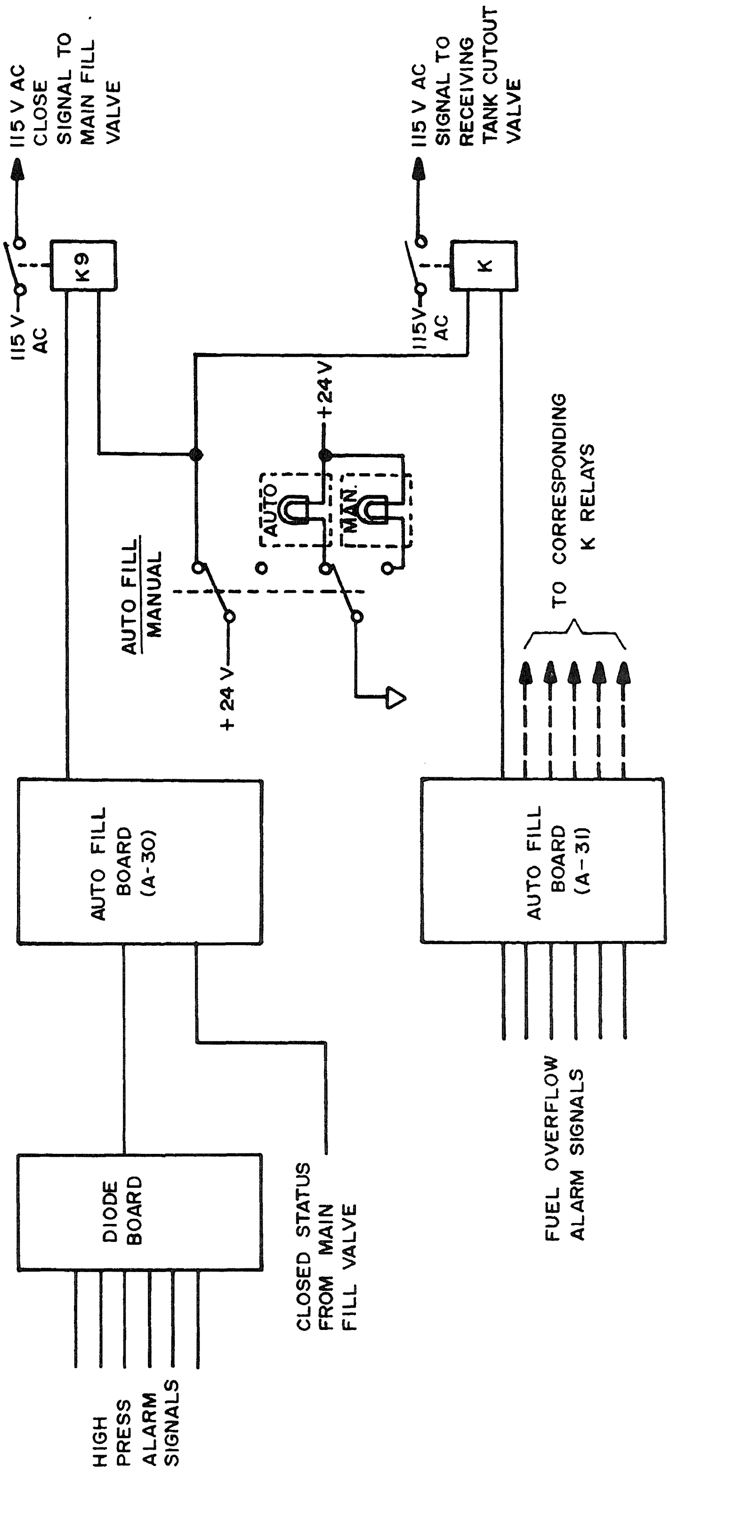
FUEL OIL AND AUTO FILL CIRCUIT

The FO auto fill circuit (figure 9-45) is located in the FSCC. When enabled, it provides two

Table 9-5.—Pump and Purifier Remote Control Locations

EQUIPMENT	FSCC	FO LOCAL PANEL	JP-5 LOCAL PANEL
FO Transfer Pumps	ON/OFF	ON/OFF	---
FO Purifiers	OFF only	ON/OFF	---
Biocide Pump	ON/OFF	---	---
JP-5 Transfer Pump	OFF only	---	ON/OFF
JP-5 Service Pump	OFF only	---	ON/OFF

NOTE: All Pumps and Purifiers have OFF/ON Control at the associated motor controller.



RELAY IDENTIFICATION

K1 AFT. PORT	K4 AFT. STBD.
K2 MID. PORT	K5 MID. STBD.
K3 FWD. PORT	K6 FWD. STBD.

293.74

Figure 9-45.—Fuel oil auto fill circuit.

functions: it closes the main fill valve as necessary to relieve a HP condition in any FO receiving tank, and it closes the cutout valve for a tank bank when that bank is nearly full.

Diode board A12 receives HIGH PRESS hazard alarm signals from each of the six receiving tank pressure hazard alarm boards. If an alarm signal is present on any one or any combination of these inputs, the diode board outputs a signal to the auto fill board A30. The auto fill board switches the K9 relay return to common. If the auto fill pushbutton indicator is in the auto fill mode, relay K9 picks up. The contacts of relay K9 outputs a 120-volt a.c. close signal to the main fill valve controller. The valve will turn in the close direction until the following conditions are met: (1) all alarm inputs are removed from the diode board, (2) the auto fill board receives a closed status from the main fill valve, or (3) the valve reaches the closed limit switch, de-energizing the controller.

The auto fill board A30 received inputs from each of the FO last position storage tank hazard alarm cards. If a FUEL OVERFLOW alarm signal is present on one of these inputs, the auto fill board switches the corresponding K relay return to common. If the auto fill mode was selected, the K relay for that tank bank outputs a 120-volt a.c. close signal to the receiving tank cutout valve for the tank bank. The valve will close fully, ending filling for that bank. When the valve has closed, a closed signal from the valve limit switch causes the auto fill board to de-energize the K relay. Figure 9-45 identifies the K relay for each tank bank.

JP-5 AUTO FILL CIRCUIT

The JP-5 auto fill circuit is also located in the FSCC. When enabled, its function is to close the fill valve to a JP-5 storage tank when that tank is full.

This circuit functions in the same manner as the receiving tank cutout valve circuits of the FO auto fill. If one of the JP-5 storage tank monitoring circuits starts a high-level hazard alarm, the hazard alarm card for that circuit outputs an alarm signal to the auto fill board A31. The auto fill board will energize a K relay. This causes the fill valve for that tank to close. When the valve reaches the closed position, a signal from the valve limit switch causes the auto fill board to de-energize the K relay. Relay K8 is used for the starboard tank; relay K7, for the port.

OPERATION

This section is limited to general procedures for the FSCC and local panel power application, turnoff, and self-test. You can find detailed instructions for starting, operating, and securing this equipment in NAVSEA 0915-022-7010.

Power Application

The FSCC is energized from the fuse and CB panel. The three power supply panel switches (S1, S2, and S3) should be in the ON position. Placing the main power CB (CB1) in the ON position then energizes the FSCC. All power supply indicator lights should be on. Since application of power to the console may alarm some circuits, all flashing pushbutton indicators should be depressed to reset the alarm circuitry.

Energizing the JP-5 local control panel and the FO local control panels is done by placing the a.c. power CBs in the ON position. To reset any alarms, depress any flashing pushbutton indicators.

Self-Tests

The FSCC and the three local panels are equipped with alarm and lamp tests. Depressing the HAZARD ALARM TEST pushbutton causes each hazard alarm circuit in the associated panel to start a hazard alarm (4-Hz flashing indicator and 4-Hz tone). You must acknowledge each hazard alarm. This test also starts associated remote hazard alarms. Depressing the FAULT ALARM TEST pushbutton causes each fault alarm circuit in the associated panel to start a fault alarm (1-Hz flashing indicator and 1-Hz tone). Releasing the pushbutton will end this test. Depressing the LAMP TEST pushbutton lights all indicator lights not checked by one of the alarm tests.

Normal Securing

The FSCC is secured by placing the main power CB to the OFF position. The local panels

are secured by placing the AC POWER switch to the OFF position.

DAMAGE CONTROL CONSOLE

This section describes the major components and circuit functions of the DCC located in the CCS, adjacent to the FSCC. The DCC operates as an independent system from the FSCC and the ECSS. The only interface between the DCC and the ECSS is information received for GTM fire conditions. The FSCC and the DCC are both manufactured by the same vendor. They have many similar hardware items and circuit designs.

CONSOLE DESCRIPTION

The DCC (figure 9-46) has three cabinet assemblies bolted together to form the console. These three sections, designated 1A1, 1A2, and 1A3, contain the card cages, power supplies, fuse and CB panel, and interconnection panels. These components are accessible by swingout doors and pullout power supply drawers located on the back side. On the front side of the console are two operator's panels, the hazard detection panel (1A4) and the firemain panel (1A5). These panels have all the meters, indicators, and switches needed for normal operation of the panel.

Power Supplies

There are nine d.c. power supplies in the DCC located in the power supply drawers. There are two power supplies each for +5 volts, −5 volts, and +12 volts. Three power supplies are used for the +24 volts. Each power supply has an adjustment potentiometer for maintenance calibration.

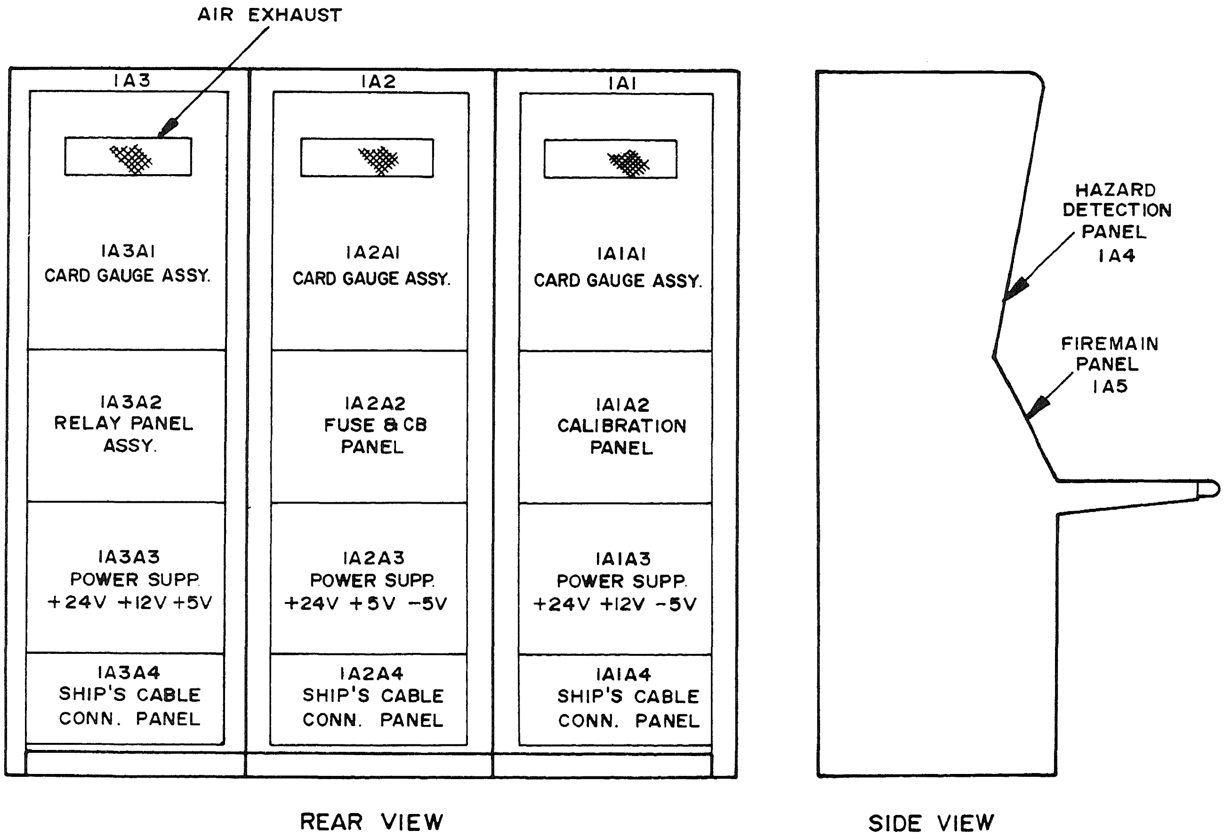


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Figure 9-46.—Damage control console component location.

Because of the redundant power supplies, console operation is unaffected if one supply for a particular voltage level should fail. If one supply of that group should fail, the remaining supply/supplies automatically assume(s) the load. Isolating diodes prevent the failed supply from absorbing current. The LED for the failed supply will go out, indicating that the supply has stopped supplying voltage. At the same time, the POWER SUPPLY FAIL light on the firemain panel illuminates. This shows that one of the nine power supplies is out of tolerance. The back panel of each power supply drawer contains the LEDs and a.c. fuses for each power supply and the drawer blower fuses.

Card Cages

Sections 1A3A1, 1A2A1, and 1A1A1 house the three card cage assemblies with the 155 PCBs used in monitoring, alarm, and control functions. One tab of each card is used to form a series circuit through all card receptacles in all three cages and the meter circuit card. Should this circuit be disturbed (card removed), the meter circuit board will illuminate the CARD REMOVED indicator on the firemain panel.

Fuse and Circuit Breaker Panel

Section 1A2A2 of the DCC has the fuse and CB panel. This panel contains the fuses to protect the console's 120-volt a.c. control circuits used for fire pump control and vent fan control. This panel also has the 24-volt d.c. fuses supplying the hazard detection and firemain panels. The main power CB supplying 120 volts a.c. to the console and the three power supply drawer switches are also on this panel.

Calibrate Panel

Section 1A1A2 has the DCC calibrate panel. This panel contains the pushbuttons and potentiometers necessary to set alarm points for low loop and low riser pressure circuits and to set full scale on both firemain panel pressure meters. It also has fuses for loop and riser pressure transducer circuits.

The LP alarm points for loop and riser circuits are set by depressing the PUSH TO SET ALARM POINT pushbutton and LOW PRESSURE/METER pushbutton at the same time for a particular point. The LOOP AND RISER PRESSURE meter will read directly the alarm set point. By adjusting the associated ADJUST potentiometer on the calibrate panel, you can set the alarm point to the desired value. Releasing the two pushbuttons returns the circuit to the normal condition.

Depressing the PUSH TO SET FULL SCALE pushbutton for either the loop and riser or pump discharge meters will send a full scale signal to the meter. You can then make the adjustment to the meter by using the mechanical full scale adjust on the meter body.

Relay Panel Assembly

Section 1A3A2 contains the relay panel. On the front of this panel are seven lighted pushbuttons. Pushbuttons S-2 through S-7 are used in testing the automatic fire pump control circuits for pumps 1 through 6. A satisfactory test of a circuit is shown by illumination of the pushbutton after it is depressed. Pushbutton S-1, LAMP TEST, is used to test the lights on this group of pushbuttons.

On the rear of the panel are nine relays used for automatic starting of fire pumps, summary fire alarms, and to inhibit start-up of fire pumps during circuit tests. Associated with each relay is a suppression diode for circuit protection.

Operator's Panels

The upper operator's panel (1A4) is designated the hazard detection panel. The lower operator's panel (1A5) is designated the firemain control panel. Both panels are shown in a foldout at the end of this chapter (figure 9-47).

The hazard detection panel has all the indicators for the fire, smoke, temperature, and bilge hazard alarm circuits. Also provided are pushbutton indicators to begin panel tests and to acknowledge alarms. The only control functions

of this panel are vent fan shutdown and summary fire alarm manual initiation.

The firemain control panel has the indicators and controls used to monitor the performance and status of the fire pumps, firemain risers, and firemain loops. Both automatic and manual starting of fire pumps is done from this panel. Also, the 1000 gpm aqueous film forming foam (AFFF) hangar sprinkler system is controlled from this panel. Included are pushbutton indicators for the start of panel fault, hazard, and lamp tests. This panel has a console status section to display certain abnormal conditions in the console.

CIRCUIT FUNCTIONAL DESCRIPTION

The following paragraphs describe major basic functions of the monitor and control circuits that support the hazard detection panel and firemain control panel. The electronic components that accomplish these functions are on the PCBs housed in the card cages.

Hazard Detection Circuits

All the alarm circuits associated with the hazard detection panel provide monitoring for both fault and hazard conditions. A typical hazard detection circuit has a sensor or group of sensors, a fault and hazard alarm card, a panel-mounted pushbutton indicator, inputs from the oscillator, and alarm status outputs to the audible, summary and alarm driver circuit card. Figure 9-48 shows a simplified hazard detection circuit.

The sensor circuits provide current signals to the fault and hazard alarm card. A sensor circuit may consist of a single sensor or up to five sensors in parallel. Four types of devices are used for fire and smoke detection.

1. Thermostatic Switches—These switches will change state when a specific temperature is reached. Three models are used in the system, providing alarm points of 105 °F, 125 °F, and 150 °F. Application of these switches has been selected considering the normal environment of the associated compartment. Typically, the 105 °F switches are used in magazines and other spaces where ammunition or critical propellants are stored. The 125 °F switches are used for flammable liquid storerooms, paint mixing and issue rooms, spaces for compressed gas storage, aviation storerooms, and other spaces with flammable liquids. The 150 °F switches are used for miscellaneous storerooms and lockers.

2. Fixed Temperature and Rate of Rise Detectors—These sensors change state at a specific temperature (105 °F, 125 °F, or 150 °F) or if the rate of temperature increase exceeds 15 °F per minute. These sensors are used in certain non-critical storage spaces. Specific sensors were selected considering the normal environment of the space.

3. Ionization Detectors—These detectors sample the environment or products of combustion. An ionization detector will typically change state at 40-percent Dioctylphthalate Aerosol concentration (about 2- to 3-percent smoke). Ionization detectors are installed in crew living areas and all ship electronic spaces not provided with Ⓦ ventilation. Direct sampling ionization detectors are installed in Ⓦ ducts serving ship electronic spaces and crew living areas.

4. Manual Pull Stations—In addition to the temperature and smoke detectors, nine manual pull stations are provided. They allow remote activation of a fire alarm. Pull stations are located in main engineering spaces, selected passageways, and at the helicopter hangar door.

Each sensor circuit ends in an end-of-line resistor. This establishes a normal condition current flow in the sensor line. Should any sensor in the line detect a hazardous condition and change state, the current in the sensor line will increase to an alarm level. If the sensor circuit opens at any time, the current in the circuit will drop below the normal value, indicating a fault in the circuit.

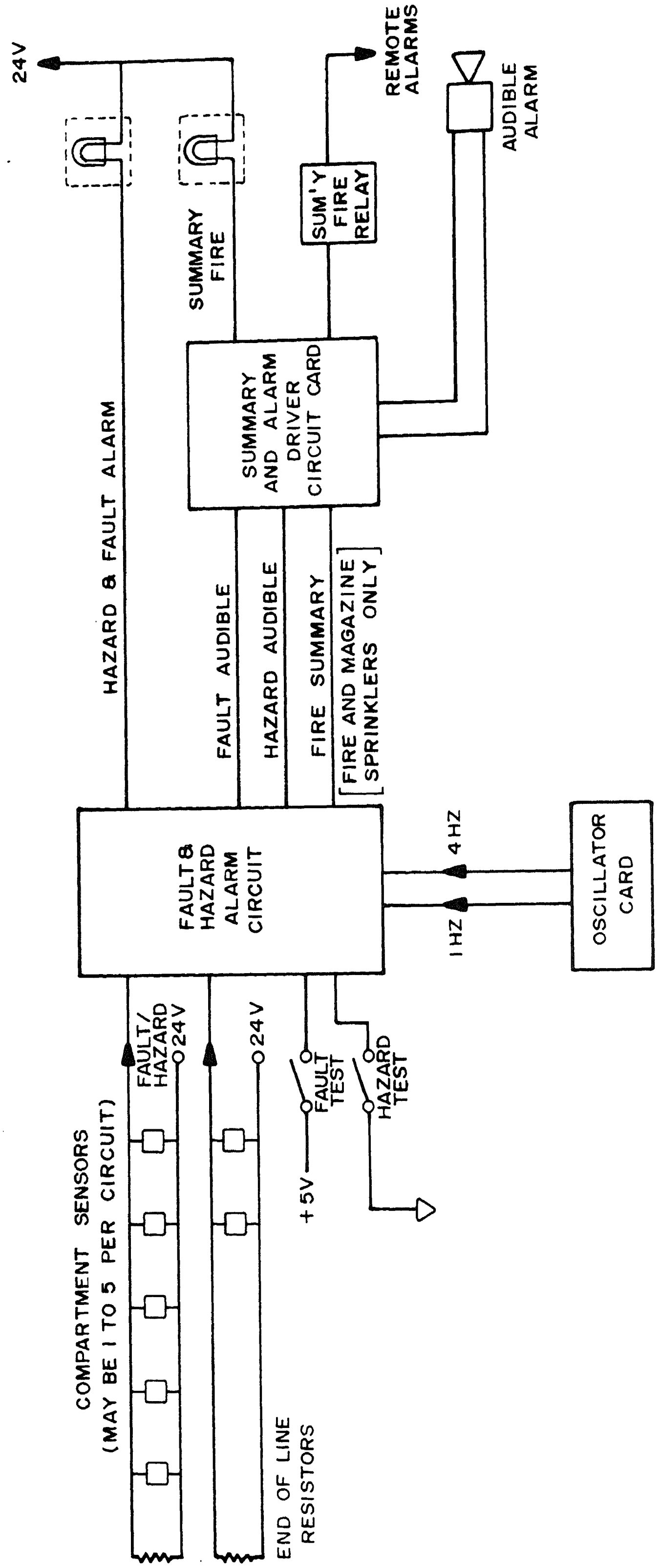

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Figure 9-48.—Typical DCC hazard detection circuit.

Table 9-6.—Sensor Input Loop, Normal and Alarm Circuit Levels

SENSOR	NON-ALARM CONDITION	HAZARD ALARM STATE	FAULT ALARM STATE
Fire, thermal and manual pull station only	13.5 mA ±2 mA	60 mA (min.) 71 mA (max.)	less than 8 mA
Thermal, rate-of-rise, and smoke only	13.5 mA ±2 mA	30 mA +10 mA − 3 mA	less than 8 mA
All others	2 mA ±0.5 mA	5 mA ±1 mA	less than 0.5 mA

Table 9-6 gives the sensor input loop current values for different circuit conditions. Sensor loops that detect fire conditions operate with higher current values than do other types of loop.

The sensor circuit current is sent through a fault and hazard alarm card. Each of these cards has two comparator circuits to accommodate two sensor circuits. Each comparator has provisions to accept either a high-current or low-current sensor circuit.

If the current in the sensor loop exceeds the preset alarm threshold, the fault and hazard alarm card will begin a hazard alarm output. This causes the associated indicator light to flash at a 4-Hz rate. The audible, summary and alarm driver card will sound the audible alarm at the same 4-Hz rate. When the fault and hazard alarm card receives an acknowledge signal, it will remove the signal to the audible, summary and alarm driver card. This silences the audible alarm (if no additional alarms exist). At the same time, the signal to the indicator light goes to a steady state. The circuit remains in this condition until the current in the sensor circuit drops below the alarm threshold. At this time, the indicator light goes out.

If the sensor line current drops below the fault alarm threshold, the fault and hazard alarm card starts a fault alarm. The fault alarm has the audible alarm pulsed at a 1-Hz rate and the associated indicator flashing at a 1-Hz rate. When the fault and hazard alarm card receives an acknowledge signal in response to a fault alarm, it removes the audible alarm signal. This indicator remains flashing, however, until the sensor line current goes above the fault alarm threshold.

The hazard detection circuits are provided with hazard and fault test functions. Pushbutton indicators on the hazard detection panel show these tests. If one of the HAZARD ALARM TEST pushbuttons is depressed, a common hazard test signal is sent to the fault and hazard alarm cards for that section of the panel. This signal will cause each comparator to latch into the alarm state. The 4-Hz visual and audible alarms are energized. Depressing the ALARM ACK pushbutton (with HAZARD ALARM TEST held depressed) tests the acknowledge functions. This will silence the audible alarm and steady all indicators. Releasing the HAZARD ALARM TEST pushbutton and depressing the ALARM TEST and the ALARM ACK pushbuttons will reset the circuits to the normal state. The summary fire relay is disabled during this test. This prevents activation of the remote summary fire alarms.

Depressing a FAULT ALARM TEST pushbutton indicator applies a 5-volt fault test signal to the fault and hazard alarm card associated with that portion of the panel. This causes each comparator to go into the fault alarm state. Then a 1-Hz audible alarm and all associated indicators will flash at the 1-Hz rate. Acknowledging this test alarm (while holding FAULT ALARM TEST depressed) silences the audible only. Releasing the FAULT ALARM TEST pushbutton ends the test and restores the circuits to normal operation.

The hazard detection panel is divided into two sections for these tests with corresponding pushbuttons for each. The dividing line is about frame 280. This division is made to prevent

overloading of the circuits by having all indicators on at one time. The two pushbuttons are electrically interlocked. This prevents simultaneous testing of both halves.

Summary Fire Circuit

The summary fire alarm circuit shows a fire somewhere in the ship. The basic components of this circuit include the audible, summary and alarm driver card, a SUMMARY FIRE ALARM pushbutton indicator, a summary fire alarm relay (K9), and remote alarms at each quarterdeck and on the bridge.

As shown in figure 9-48, hazard detection circuits associated with fire detection and magazine sprinkle activation input a fire summary signal to the audible, summary and alarm driver card. If any alarm signal exists on these inputs, the driver card energizes the summary alarm relay and illuminates the SUMMARY FIRE ALARM light on the hazard detection panel. The summary alarm relay activates the alarm mechanism at the three remote locations. These remote alarms must be silenced at the remote location. The summary fire relay remains energized as long as the hazard detection circuit is in an alarm state.

In addition to the hazard detection circuit inputs, the audible, summary and alarm driver card receives an input from the SUMMARY FIRE ALARM pushbutton indicator. When this button is depressed, the summary fire relay is energized and the panel indicator illuminated. This allows the DCC operator to start a summary fire alarm for a fire condition not detected by a hazard detection circuit.

Vent Fan Shutdown Control

Each of the four zones on the hazard detection panel has VENT FAN SHUTDOWN CONTROL pushbutton indicators. They are associated with the Ⓦ and Z ventilation systems. They provide ON/OFF status for the vent systems for each zone. They enable the DCC operator to shut down selected systems.

Zone 1 (frame 28 to 138) has a Ⓦ pushbutton indicator. When this is depressed, a 120-volt a.c. off signal is sent to a vent shutdown relay in load center (LC) 11. The relay then latches in the OFF state. This causes the shunt trip coil to open both the normal and alternate CBs feeding the power panel that supplies the vent fans for this zone. The Ⓦ ventilation for zone 1 will be secured. There is no ON vent fan control at the DCC. To restore the system to normal operation, you must depress the VENT RESET pushbutton at LC 11. This changes the vent shutdown relay to the ON state. You must close the normal and alternate supply CBs and restart each vent fan at its motor control station. The sequence for zones 2, 3, and 4 is the same, except that multiple shutdown relays and feeder breakers may be involved.

Firemain System Pressure Monitoring

The firemain system pressure is monitored at 15 points. The nine loop and riser monitoring circuits use a common LOOP AND RISER PRESSURE 0 to 200 psig panel meter to display pressures from selected points. This common meter also provides hazard alarming for LP conditions. The six fire pump discharge circuits use a common PUMP DISCHARGE PRESSURE 0 to 200 psig panel meter to display pressures from selected points.

The pressure transducers used at these 15 points are similar to the type used in the FO fill and transfer system. These transducers have their own signal conditioning circuits. They cause a 4- to 20-mA signal to flow that is proportional to pressure.

A simplified loop and riser pressure monitoring circuit is shown in figure 9-49. The 4- to 20-mA pressure signal is routed through its meter selector pushbutton to a fixed resistor (R2) and returns to −5 volts. If the selector pushbutton for this transducer is depressed, the level signal will be sent through the LOOP AND RISER PRESSURE meter. The pressure level will be displayed. The selector pushbutton has holding coils that latch the selected circuit to the meter once the pushbutton has been depressed. The holding coil circuits are interlocked so that depressing one selector pushbutton will open the other holding circuits. Therefore, once a selector pushbutton has been depressed, that pressure parameter will be displayed continuously until another point is selected. Additionally, the interlocking prevents more than one point being selected at once. The selector pushbutton energizes the light on its indicator. This indicates which

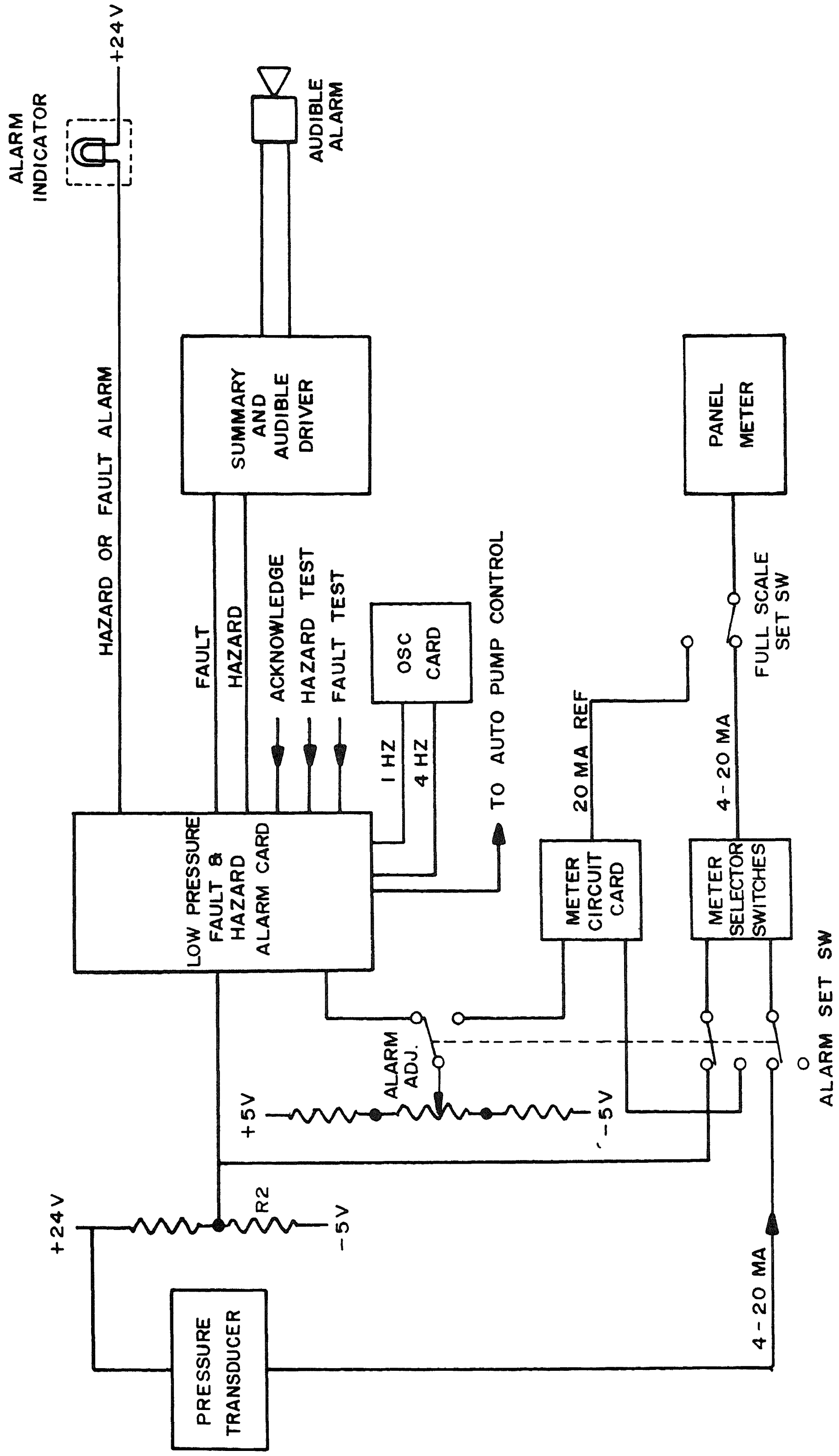

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Figure 9-49.—Simplified pressure monitor circuit.

pressure is being displayed. The LP fault and hazard alarm card receives a voltage signal proportional to pressure. This signal is compared to the alarm reference. If the pressure signal drops below the alarm reference, the LP fault and hazard card will start a hazard alarm. The LOW PRESSURE indicator on the firemain panel will flash at a 4-Hz rate. A hazard alarm signal will be sent to the audible, summary and alarm driver. This will sound the audible alarm at the 4-Hz rate. When the fault and hazard alarm card receives an acknowledge signal, the hazard output to the audible, summary and alarm driver will be removed. This silences the audible alarm. The flashing indicator will go steady. When the pressure signal goes above the alarm reference, the fault and hazard circuit will return to normal. The indicator light will extinguish.

Fault alarm initiation is also provided by this circuit. If current drops to zero in the pressure transducer circuit, the fault and hazard alarm card detects a loss of voltage across the sensing resistor (R2). A fault alarm will be initiated. The indicator will flash at a 1-Hz rate. At the same time, a fault alarm signal will be sent to the audible, summary and alarm driver. This will sound the audible alarm at a 1-Hz rate. When the LP fault and hazard card receives an acknowledge signal, the output to the audible, summary and alarm driver is removed. The audible alarm will stop. This will not affect the flashing indicator. The fault circuit does not latch. It will return to normal whenever the transducer circuit current is restored.

The firemain control panel has a HAZARD ALARM TEST and a FAULT ALARM TEST pushbutton indicator. These function similar to the hazard detection panel hazard and fault tests. They simulate hazard and fault conditions in the LP fault and hazard cards.

You can adjust LP alarm points by using the PUSH TO SET ALARM POINT and ADJUST functions of the calibrate panel. When the PUSH TO SET ALARM POINT pushbutton is depressed, the alarm reference signal is removed from the LP fault and hazard card and routed to the meter circuit card. If the meter selector pushbutton has been depressed, the meter will read the alarm point for that circuit. You can then adjust the ADJUST potentiometer to obtain the desired alarm point. Releasing the pushbutton will return the circuit to normal operation. You can set alarm points from 20 to 150 psig.

The calibrate panel is also used in calibrating full scale reading for the LOOP AND RISER PRESSURE meter. When this PUSH TO ADJUST FULL SCALE pushbutton is depressed, a 20-mA reference signal from the meter circuit card is routed to the meter. Adjustment of the meter reading is done using the mechanical full scale adjustment on the meter. Releasing the pushbutton returns the meter to normal operation.

Fire pump discharge pressure monitoring circuits do not have fault and hazard detection functions. The 4- to 20-mA pressure signal from the transducers is routed to the meter selector pushbutton and to the PUMP DISCHARGE PRESSURE meter if the pushbutton is depressed. Selector pushbutton interlocking is similar to the loop and riser circuit. Only one point can be selected at a time. That point will be displayed continuously until another pushbutton is depressed. The PUMP DISCHARGE PRESSURE meter full scale reading is established similar to the LOOP AND RISER PRESSURE meter.

Fire Pump Control

The firemain panel provides monitoring and remote control of the six fire pumps. The pump discharge pressures are displayed on a common PUMP DISCHARGE PRESSURE meter. Pump ON/OFF status is displayed by individual pushbutton indicators for each pump. Manual and automatic modes of pump control are available at the panel. Figure 9-50 shows a simplified fire pump control diagram.

MANUAL CONTROL.—Manual control is by 12 (2 for each pump) momentary action pushbutton indicators. The ON and OFF pushbuttons supply 120-volt a.c. to the ON and OFF relays in the pump controllers for starting and stopping the pumps. Auxiliary contacts at the controllers are fed back to illuminate the ON and OFF indicators.

AUTO CONTROL.—Auto control is done by logic in the DCC. The components of this circuit are the auto pump driver card and the relays in the relay panel. The auto pump logic card

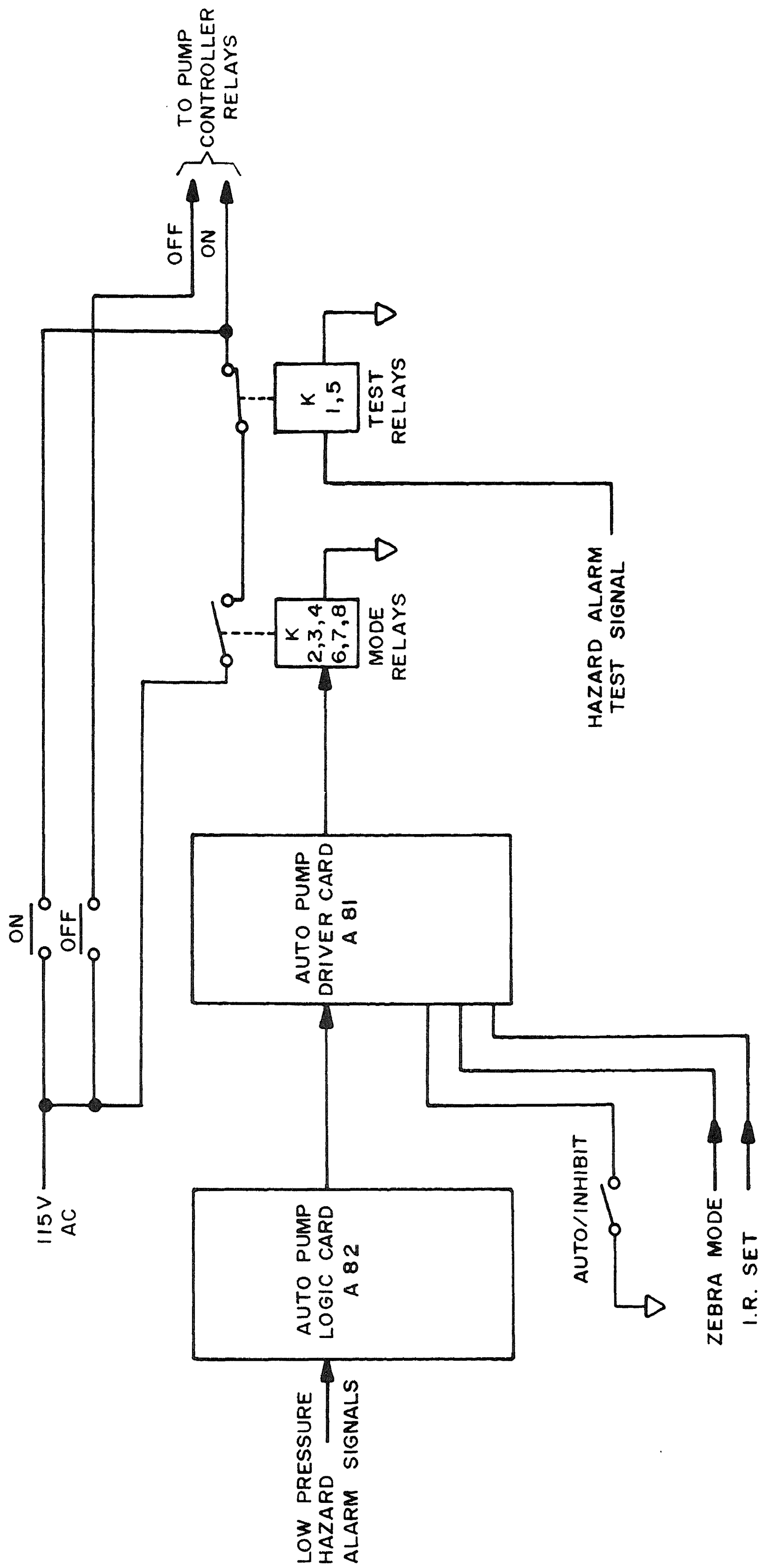

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Figure 9-50.—Simplified DCC fire pump control diagram.

responds to inputs from the six riser LP hazard alarm circuits. Outputs from the logic card energize a relay driver in the auto pump driver card. This, in turn, energizes the required relay. It supplies 120 volts a.c. to the ON relay at the pump controller to start a pump. Auto control mode for a particular pump is in effect only when the associated AUTO/INHIBIT selector is in the AUTO position. The auto control logic provides four operating modes discussed in the following paragraphs.

NORMAL MODE.—A riser LP alarm starts the auto control (after a 0.5-second time delay to eliminate response to transients). At the end of this time delay, the lowest numbered alarmed riser fire pump is started, if not inhibited or already running. After a 1- to 5-second delay (adjustable), the next highest numbered pump, whose riser LP alarm is on, starts. This procedure continues in sequence until no alarms remain. Auto pump control then resets.

ZEBRA MODE (SEGREGATED LOOP).—Zebra mode is established when all four Zebra mode pushbutton indicators are in the CLOSE position. Auto control operation is then as in normal mode except the 1- to 5-second time delay is eliminated. This allows simultaneous starting of additional pumps if required.

IR SET MODE (UNSEGREGATED LOOPS).—When auto control receives an IR set signal, it sequentially scans through the pumps and turns on two available (not inhibited and not already running) pumps. If a scan through the six pumps does not result in two additional pumps being turned on, the circuit resets. Operating is then returned to the normal mode.

IR SET MODE (SEGREGATED LOOPS).—When auto control sees an IR set signal, it turns on fire pumps No. 3 and No. 4 if not already on or inhibited. Auto control then returns to Zebra mode.

You can test auto control at the relay panel. You can use pushbutton indicators on the panel to simulate riser LP alarm conditions for each pump's auto control circuit. When the pushbutton is depressed, its indicator illuminates if the circuit responds satisfactorily. You can depress two or more pushbuttons simultaneously to check for proper time delays. Actual starting of the pump is inhibited during these tests.

Valve Status Monitoring

The firemain panel provides OPEN/CLOSE status monitoring for the six fire pump inlet and six fire pump discharge valves. The status of the indicator lights is controlled by limit switches on the valves.

There are OPEN/CLOSE pushbutton indicators for the firemain loop segregation valves. One is for each of the four Zebra valves. There are no valve limit switches associated with these indicators. The console operator must set their state. The pushbuttons are the latching type. They change state each time they are depressed. When all four indicators are in the CLOSE state, a Zebra mode signal is sent to the auto control circuit to modify pump logic.

Aqueous Film Forming Foam Control and Monitoring

The AFFF control and monitoring functions available from the firemain panel are as follows.

1. AFFF FP-180 system monitoring
2. 1000 gpm AFFF proportioner control and monitoring
3. AFFF hangar sprinkler control and monitoring

The AFFF FP-180 system monitoring circuits provide status of AFFF FP-180 system activation. There are four indicators on the firemain panel to indicate the operational status of the four AFFF FP-180 systems. The indicating lamps are controlled by limit switches on the individual FP-180 control valves. The lamps are illuminated (AFFF FP-180 ON) when the respective AFFF FP-180 system is activated.

Control and status of the hangar AFFF sprinkler system and the 1000 gpm AFFF proportioner is provided at the firemain panel by four indicator switches. Activation of the 1000 GPM AFFF PROP ON or OFF switches supplies 120 volts a.c. to the hangar AFFF proportioner controller for starting or stopping of the proportioner. Auxiliary contacts within the proportioner

controller are hardwired to indicating lamps on the DCC to provide proportioner ON/OFF status. Control of the hangar AFFF sprinkler valve is similar to that of the AFFF proportioner. The SPRG ON or OFF switches supply 120 volts a.c. to the valve controller to open or close the sprinkler valve. Contacts within the controller are hardwired to indicating lamps to provide SPRG ON/OFF status at the DCC.

Chemical, Biological, Radiation (CBR) Monitoring

The fireman panel has four indicators to provide ON status for each of the four CBR washdown groups. Each indicator is wired to a remote group relay which closes upon activation of the associated CBR washdown group. When the relay is closed, the respective panel indicator illuminates. No control of the washdown group is available at the DCC.

Infrared Suppression System Monitoring

Two indicator lights on the firemain control panel provide status of the IR suppression system. The IR SET indicator illuminates when an IR command has been started at either the bridge or the CIC. The IR ON indicator illuminates when one or more of the seven IR system valves open. The signals that control these indicators originate at the PACC. The IR set signal is also used to modify auto control logic.

Console Status Monitoring

The firemain control panel has a console status section to warn of abnormal conditions within the DCC itself. The monitored conditions are power supply failure, hazard oscillator failure, fault oscillator failure, console high temperature, and card removed.

POWER SUPPLY FAILURE CIRCUIT.—The power supply fail circuit monitors the output voltage level of each d.c. power supply at its power supply drawer. Each monitored voltage is sent to the meter circuit card. When any of these voltages drops below its limit, the meter circuit card will illuminate the POWER SUPPLY FAILURE indicator. To find out which supply has failed, the operator must observe the individual power supply indicator lights at each power supply drawer.

HAZARD AND FAULT OSCILLATOR FAIL CIRCUITS.—The hazard and fault oscillator card supplies both the 4-Hz and the 1-Hz rates for hazard and fault alarms. There are two oscillators circuits on the card for each rate. One is designated main and the other designated spare. Normally, the main oscillators are supplying the console. If one of the main oscillators fails, its spare will automatically take over. The oscillator card will then cause the associated oscillator fail indicator to illuminate. Console operation is unaffected, but you should replace the oscillator card.

CONSOLE HIGH TEMPERATURE MONITORING.—In each of the three cabinet assemblies of the DCC is a preset temperature switch. If the temperature at any one of these temperature switches exceeds 168 °F, the CONSOLE HIGH TEMP indicator will illuminate.

CARD REMOVED MONITORING.—Each printed circuit card in the DCC has one pin connected to an adjacent pin. These pins are all connected in series through the receptacles. This series circuit inputs to the meter circuit card. If the series circuit is interrupted by a removed or improperly seated card, the meter circuit will cause the CARD REMOVED indicator to illuminate.

CONSOLE OPERATION

This section is limited to general procedures for DCC power application, turnoff, and self-tests. Detailed instructions for starting, operating, and receiving this equipment are contained in NAVSEA 0988-138-4010.

Power Application

The DCC is energized from the fuse and CB panel. The three power supply panel switches (S1, S2, and S3) should be in the ON position. Placing the MAIN POWER CB (CB1) in the ON position will then energize the DCC. All power supply indicator lights should be on. Since

application of power to the console may cause some circuits to alarm, all flashing pushbutton indicators should be depressed to reset the alarm circuitry.

Self-Tests

The hazard detection panel and the firemain panel are equipped with alarm and lamp tests. There are HAZARD ALARM and FAULT ALARM TEST pushbuttons for each half of the hazard detection panel and for the firemain panel. Exercise each group independently. Momentarily depressing a HAZARD ALARM TEST switch causes all hazard indicators for that group to flash. The audible alarm will sound at 4-Hz rate. While holding the HAZARD ALARM TEST pushbutton depressed, depressing the ALARM ACK for the panel causes all flashing lights to go steady and silences the audible alarm. Then you may release the HAZARD ALARM TEST. Depressing ALARM ACK again extinguishes all indicators not actually in alarm and restores the circuits to normal operation.

Momentarily depressing a FAULT ALARM TEST switch causes all hazard indicators for that group to flash at a 1-Hz rate. The audible alarm will then sound at a 1-Hz rate. While holding FAULT ALARM TEST depressed, depressing the ALARM ACK for the panel causes the audible alarm to silence (indicators remain flashing). You may then release FAULT ALARM TEST. Depressing ALARM ACK again extinguishes all indicators not actually in alarm and restores the circuits to normal operation.

After all fault and hazard tests have been performed, use the LAMP TEST to check all indicator lights not tested during the alarm tests. Perform these tests upon energizing the console and at regular intervals during operation.

Normal Securing

The DCC is secured by placing the MAIN POWER CB in the OFF position.

SUMMARY

While this chapter was written to familiarize you with the operation of the consoles in the CCS of the DD-963 class ships, it is not enough information for operational or troubleshooting purposes. This material is provided to give you, a junior GSE, enough knowledge to begin qualifying on CCS watches, using the PQS applicable to the watch station you are learning.

The knowledge gained by reading this chapter should also give you enough information to assist a qualified technician in the repair of this important equipment. Only technical manuals can give you the in-depth procedures as to how to troubleshoot and repair the CCS equipment. Never try to work on this equipment without the proper manuals. The proposed *GSE 1 & C* rate training manual will also provide more information on the troubleshooting techniques and repair procedures.

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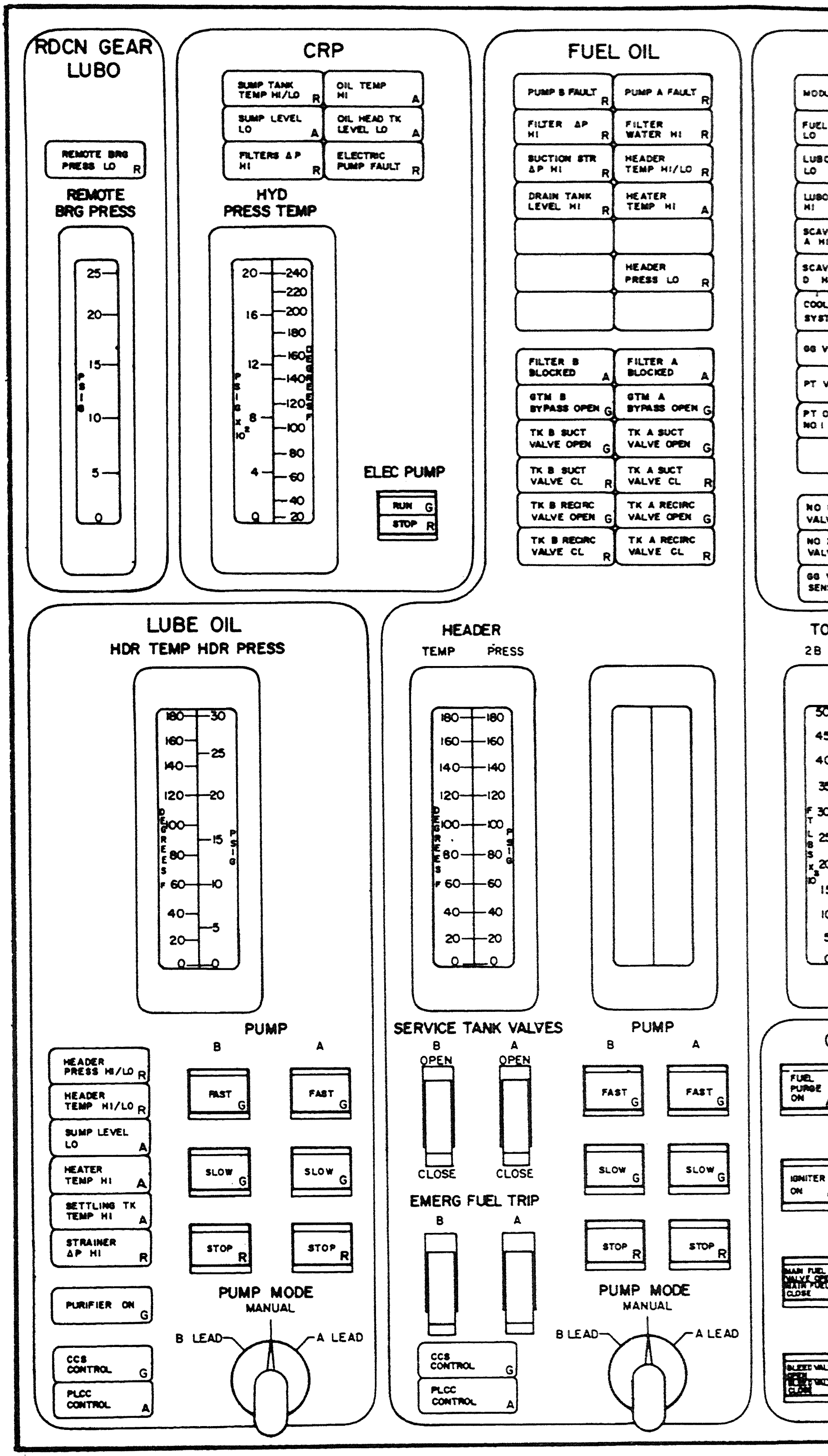
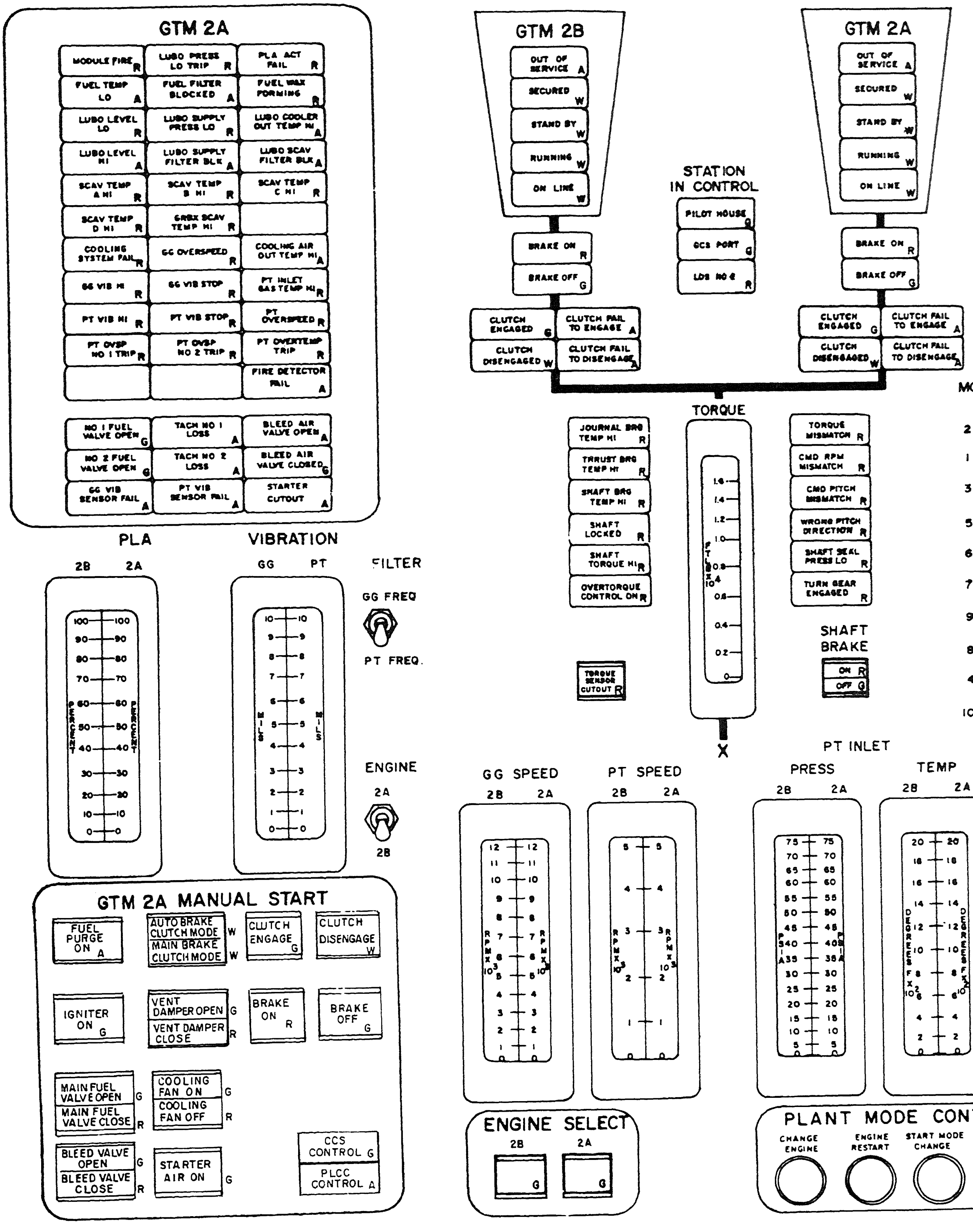
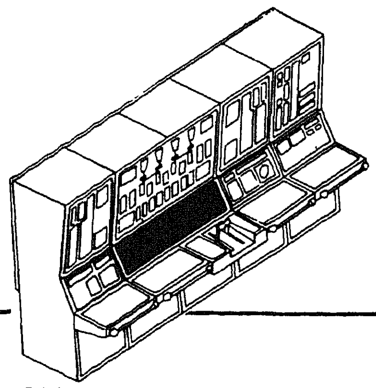
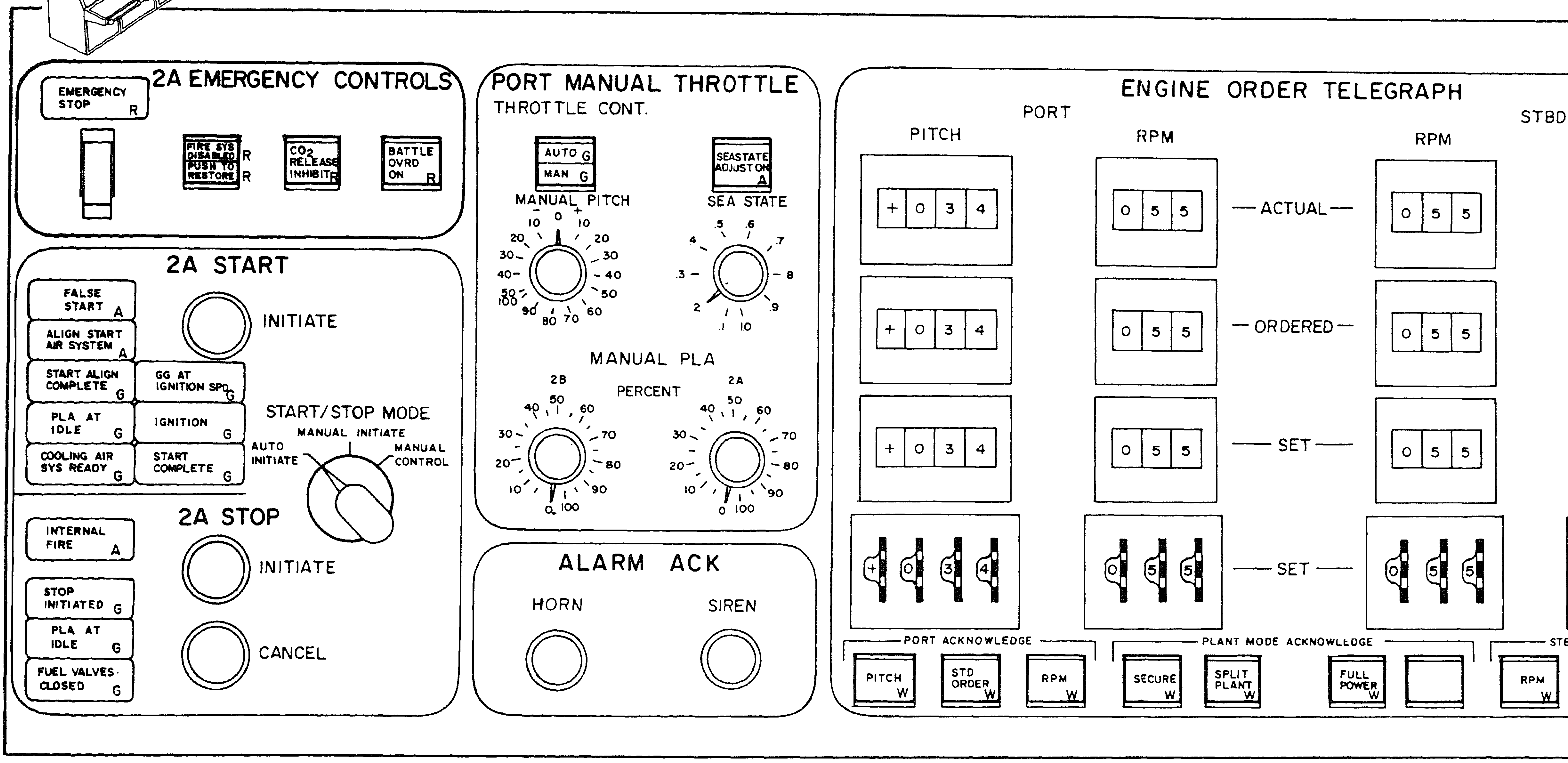


RDCN GEAR LUBO
REMOTE BRG PRESS LO R
REMOTE BRG PRESS
PSIG
CRP
SUMP TANK TEMP HI/LO R
OIL TEMP HI A
SUMP LEVEL LO A
OIL HEAD TK LEVEL LO A
FILTERS ΔP HI R
ELECTRIC PUMP FAULT R
HYD PRESS TEMP
DEGREES F
ELEC PUMP
RUN G
STOP R
FUEL OIL
PUMP B FAULT R
PUMP A FAULT R
FILTER ΔP HI R
FILTER WATER HI R
SUCTION STR ΔP HI R
HEADER TEMP HI/LO R
DRAIN TANK LEVEL HI R
HEATER TEMP HI A
HEADER PRESS LO R
FILTER B BLOCKED A
FILTER A BLOCKED A
GTM B BYPASS OPEN G
GTM A BYPASS OPEN G
TK B SUCT VALVE OPEN G
TK A SUCT VALVE OPEN G
TK B SUCT VALVE CL R
TK A SUCT VALVE CL R
TK B RECIRC VALVE OPEN G
TK A RECIRC VALVE OPEN G
TK B RECIRC VALVE CL R
TK A RECIRC VALVE CL R
LUBE OIL
HDR TEMP HDR PRESS
DEGREES F
PSIG
PUMP
B
A
FAST G
SLOW G
STOP R
HEADER PRESS HI/LO R
HEADER TEMP HI/LO R
SUMP LEVEL LO A
HEATER TEMP HI A
SETTLING TK TEMP HI A
STRAINER ΔP HI R
PURIFIER ON G
CCS CONTROL G
PLCC CONTROL A
PUMP MODE
MANUAL
B LEAD
A LEAD
HEADER
TEMP
PRESS
SERVICE TANK VALVES
OPEN
CLOSE
EMERG FUEL TRIP



GTM 2A
MODULE FIRE R
LUBO PRESS LO TRIP R
PLA ACT FAIL R
FUEL TEMP LO A
FUEL FILTER BLOCKED A
FUEL WAX FORMING R
LUBO LEVEL LO R
LUBO SUPPLY PRESS LO R
LUBO COOLER OUT TEMP HI A
LUBO LEVEL HI A
LUBO SUPPLY FILTER BLK A
LUBO SCAV FILTER BLK A
SCAV TEMP A HI R
SCAV TEMP B HI R
SCAV TEMP C HI R
SCAV TEMP D HI R
GRBX SCAV TEMP HI R
COOLING SYSTEM FAIL R
GG OVERSPEED R
COOLING AIR OUT TEMP HI A
GG VIB HI R
GG VIB STOP R
PT INLET GAS TEMP HI R
PT VIB HI R
PT VIB STOP R
PT OVERSPEED R
PT OVSP NO 1 TRIP R
PT OVSP NO 2 TRIP R
PT OVERTEMP TRIP R
FIRE DETECTOR FAIL A
NO 1 FUEL VALVE OPEN G
TACH NO 1 LOSS A
BLEED AIR VALVE OPEN A
NO 2 FUEL VALVE OPEN G
TACH NO 2 LOSS A
BLEED AIR VALVE CLOSED G
GG VIB SENSOR FAIL A
PT VIB SENSOR FAIL A
STARTER CUTOUT A
PLA
2B 2A
PERCENT
VIBRATION
GG PT
MILS
FILTER
GG FREQ
PT FREQ.
ENGINE
2A
2B
GTM 2A MANUAL START
FUEL PURGE ON A
AUTO BRAKE CLUTCH MODE W
MAIN BRAKE CLUTCH MODE W
CLUTCH ENGAGE G
CLUTCH DISENGAGE W
IGNITER ON G
VENT DAMPER OPEN G
VENT DAMPER CLOSE R
BRAKE ON R
BRAKE OFF G
MAIN FUEL VALVE OPEN G
MAIN FUEL VALVE CLOSE R
COOLING FAN ON G
COOLING FAN OFF R
BLEED VALVE OPEN G
BLEED VALVE CLOSE R
STARTER AIR ON G
CCS CONTROL G
PLCC CONTROL A
GTM 2B
OUT OF SERVICE A
SECURED W
STAND BY W
RUNNING W
ON LINE W
BRAKE ON R
BRAKE OFF G
CLUTCH ENGAGED G
CLUTCH FAIL TO ENGAGE A
CLUTCH DISENGAGED W
CLUTCH FAIL TO DISENGAGE A
STATION IN CONTROL
PILOT HOUSE G
CCS PORT G
LDS NO 2 R
GTM 2A
OUT OF SERVICE A
SECURED W
STAND BY W
RUNNING W
ON LINE W
BRAKE ON R
BRAKE OFF G
CLUTCH ENGAGED G
CLUTCH FAIL TO ENGAGE A
CLUTCH DISENGAGED W
CLUTCH FAIL TO DISENGAGE A
TORQUE
JOURNAL BRG TEMP HI R
THRUST BRG TEMP HI R
SHAFT BRG TEMP HI R
SHAFT LOCKED R
SHAFT TORQUE HI R
OVERTORQUE CONTROL ON R
TORQUE SENSOR CUTOUT R
TORQUE MISMATCH R
CMD RPM MISMATCH R
CMD PITCH MISMATCH R
WRONG PITCH DIRECTION R
SHAFT SEAL PRESS LO R
TURN GEAR ENGAGED R
SHAFT BRAKE
ON R
OFF G
X
PT INLET
GG SPEED
2B 2A
RPM X 10³
PT SPEED
2B 2A
PRESS
2B 2A
PSIA
TEMP
2B 2A
DEGREES F X 10²
ENGINE SELECT
2B 2A
G G
PLANT MODE CON
CHANGE ENGINE
ENGINE RESTART
START MODE CHANGE





2A EMERGENCY CONTROLS
EMERGENCY STOP R
FIRE SYS DISABLED R
PUSH TO RESTORE R
CO2 RELEASE INHIBIT R
BATTLE OVRD ON R
2A START
FALSE START A
ALIGN START AIR SYSTEM A
START ALIGN COMPLETE G
GG AT IGNITION SPD G
PLA AT IDLE G
IGNITION G
COOLING AIR SYS READY G
START COMPLETE G
INITIATE
START/STOP MODE
MANUAL INITIATE
AUTO INITIATE
MANUAL CONTROL
2A STOP
INTERNAL FIRE A
STOP INITIATED G
PLA AT IDLE G
FUEL VALVES CLOSED G
INITIATE
CANCEL
PORT MANUAL THROTTLE
THROTTLE CONT.
AUTO G
MAN G
SEASTATE ADJUST ON A
MANUAL PITCH
SEA STATE
MANUAL PLA
PERCENT
2B
2A
ALARM ACK
HORN
SIREN
ENGINE ORDER TELEGRAPH
PORT
STBD
PITCH
RPM
RPM
ACTUAL
ORDERED
SET
SET
PORT ACKNOWLEDGE
PLANT MODE ACKNOWLEDGE
PITCH W
STD ORDER W
RPM W
SECURE W
SPLIT PLANT W
FULL POWER W
RPM W

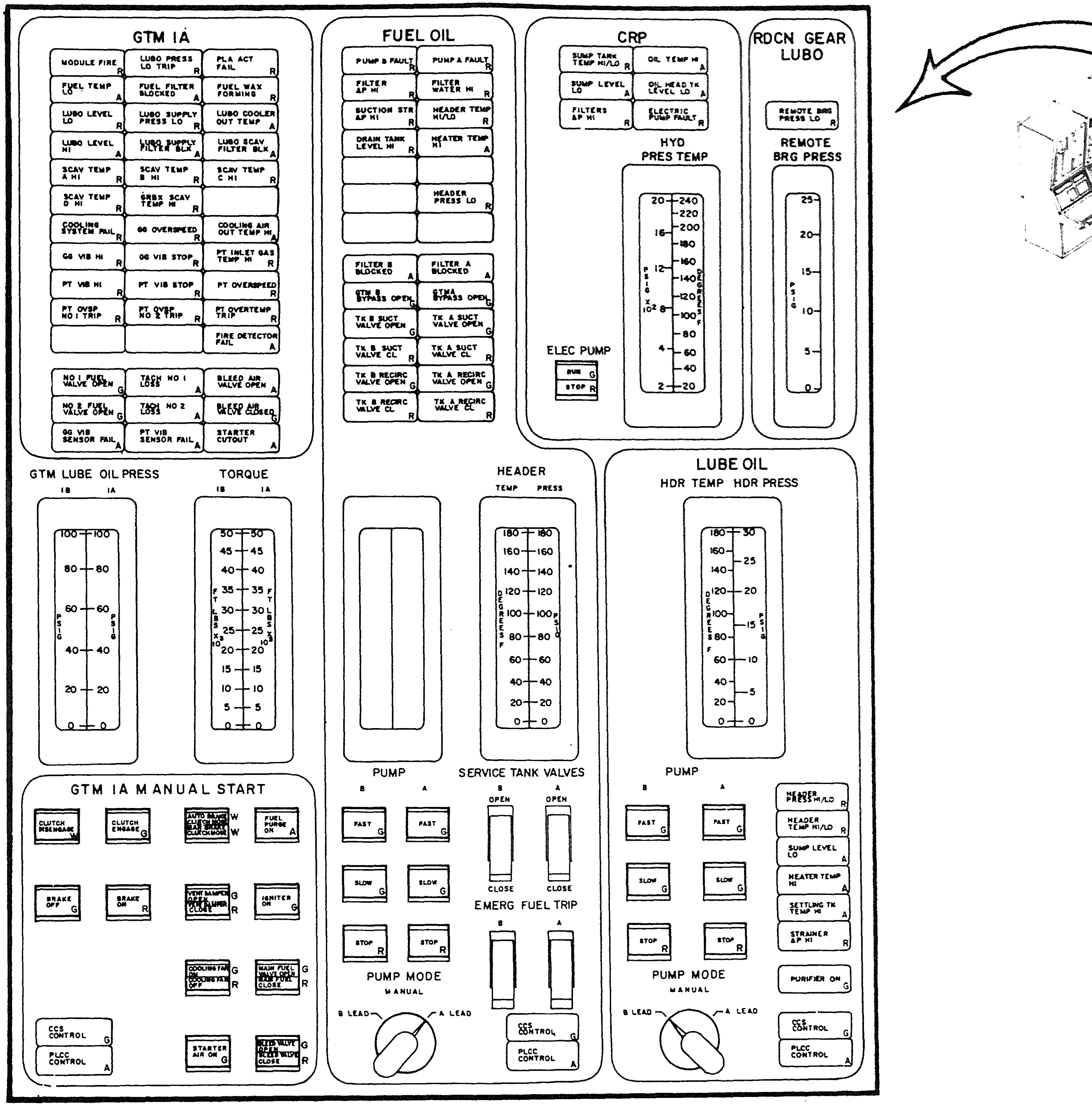
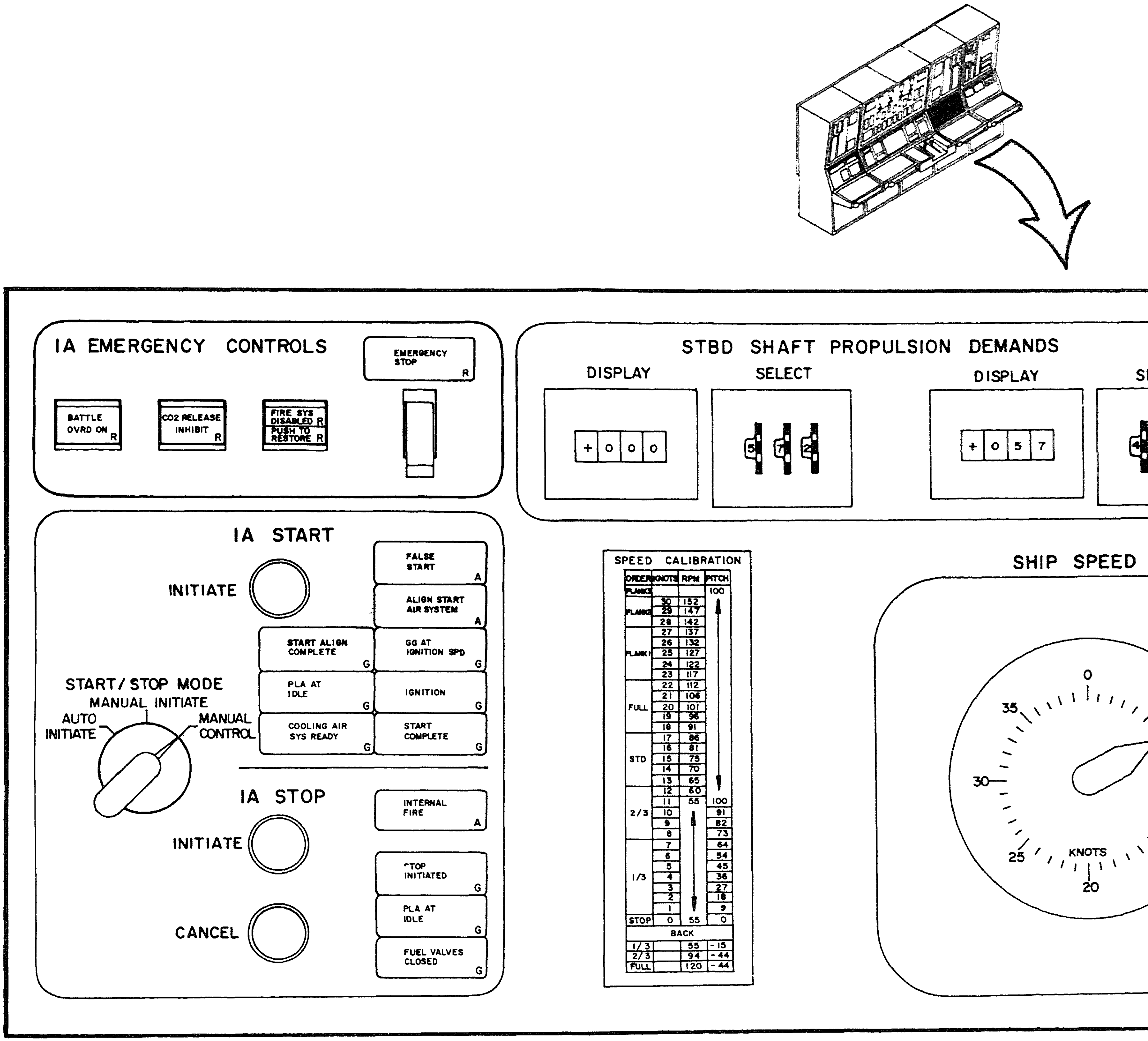


Figure 9-7.—PACC—engine No. 1 panel.



ORDER	KNOTS	RPM	PITCH
FLANK 3			100
FLANK 2	30	152	
	29	147	
	28	142	
FLANK 1	27	137	
	26	132	
	25	127	
	24	122	
	23	117	
FULL	22	112	
	21	106	
	20	101	
	19	96	
	18	91	
STD	17	86	
	16	81	
	15	75	
	14	70	
	13	65	
2/3	12	60	
	11	55	100
	10		91
	9		82
	8		73
1/3	7		64
	6		54
	5		45
	4		36
	3		27
	2		18
	1		9
STOP	0	55	0
BACK			
1/3		55	-15
2/3		94	-44
FULL		120	-44

Figure 9-8.—PACC—engine No. 1 demands panel.

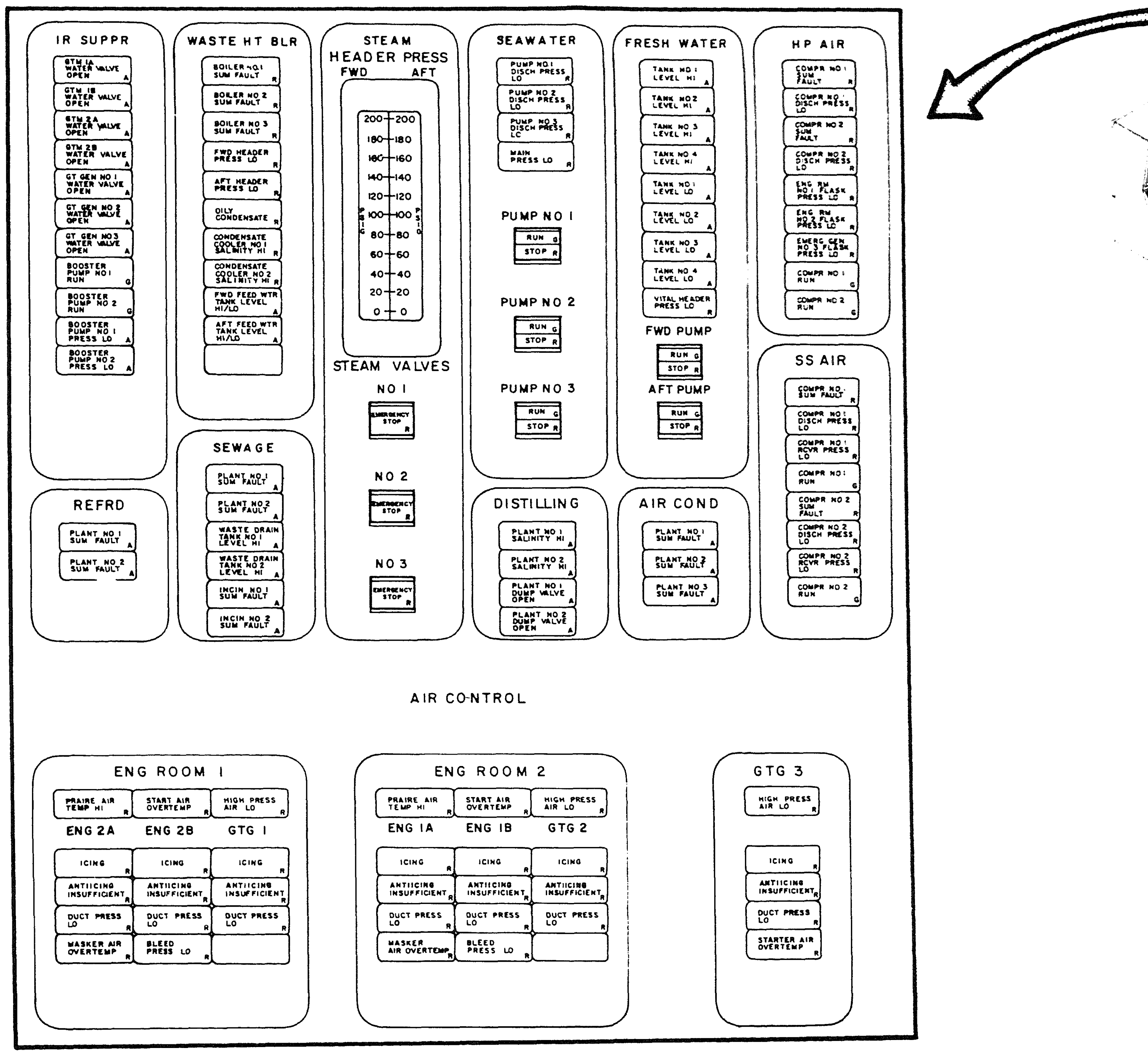


Figure 9-9.—PACC—auxiliary/bleed air panel.

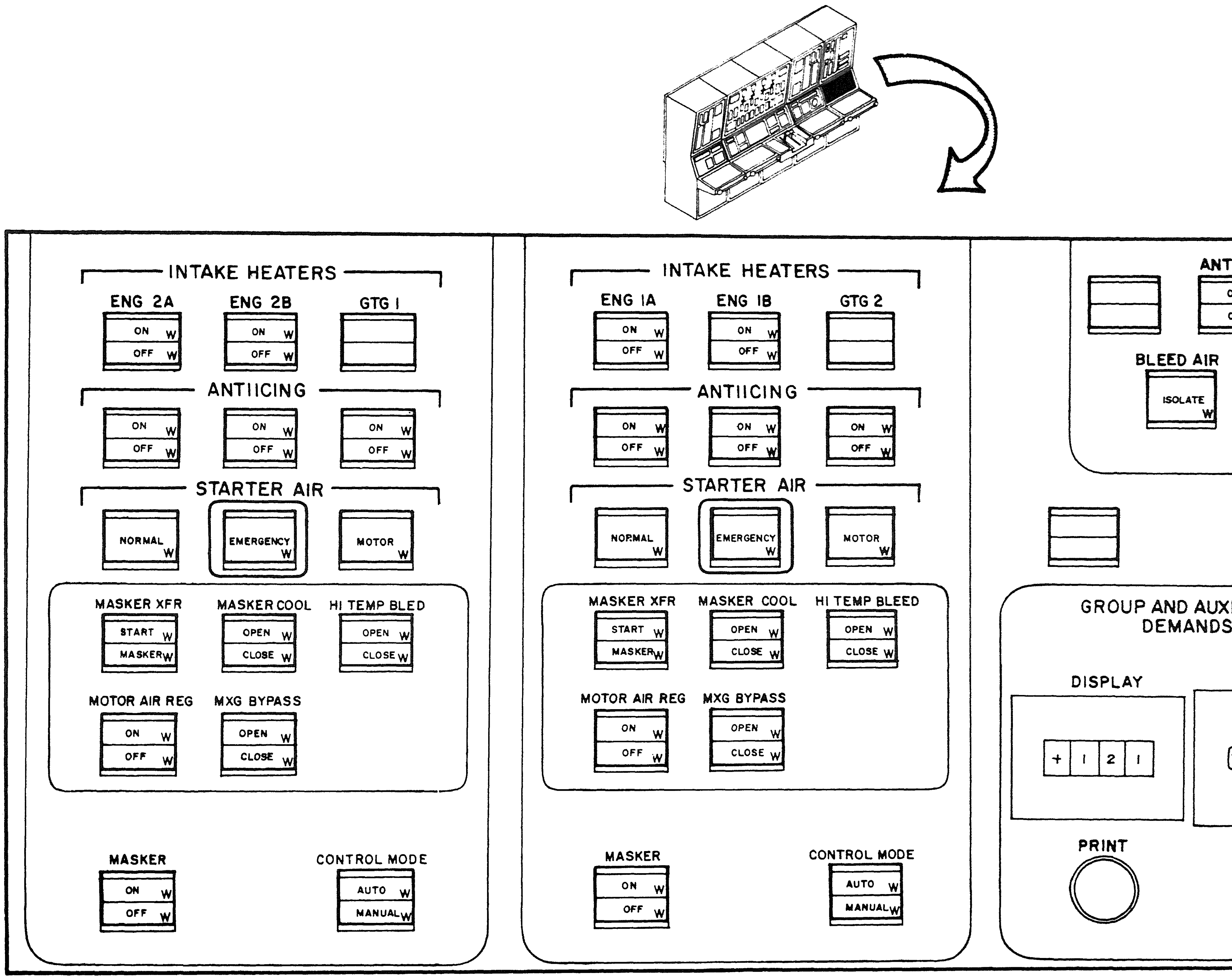


Figure 9-10.—PACC—bleed air control panel.

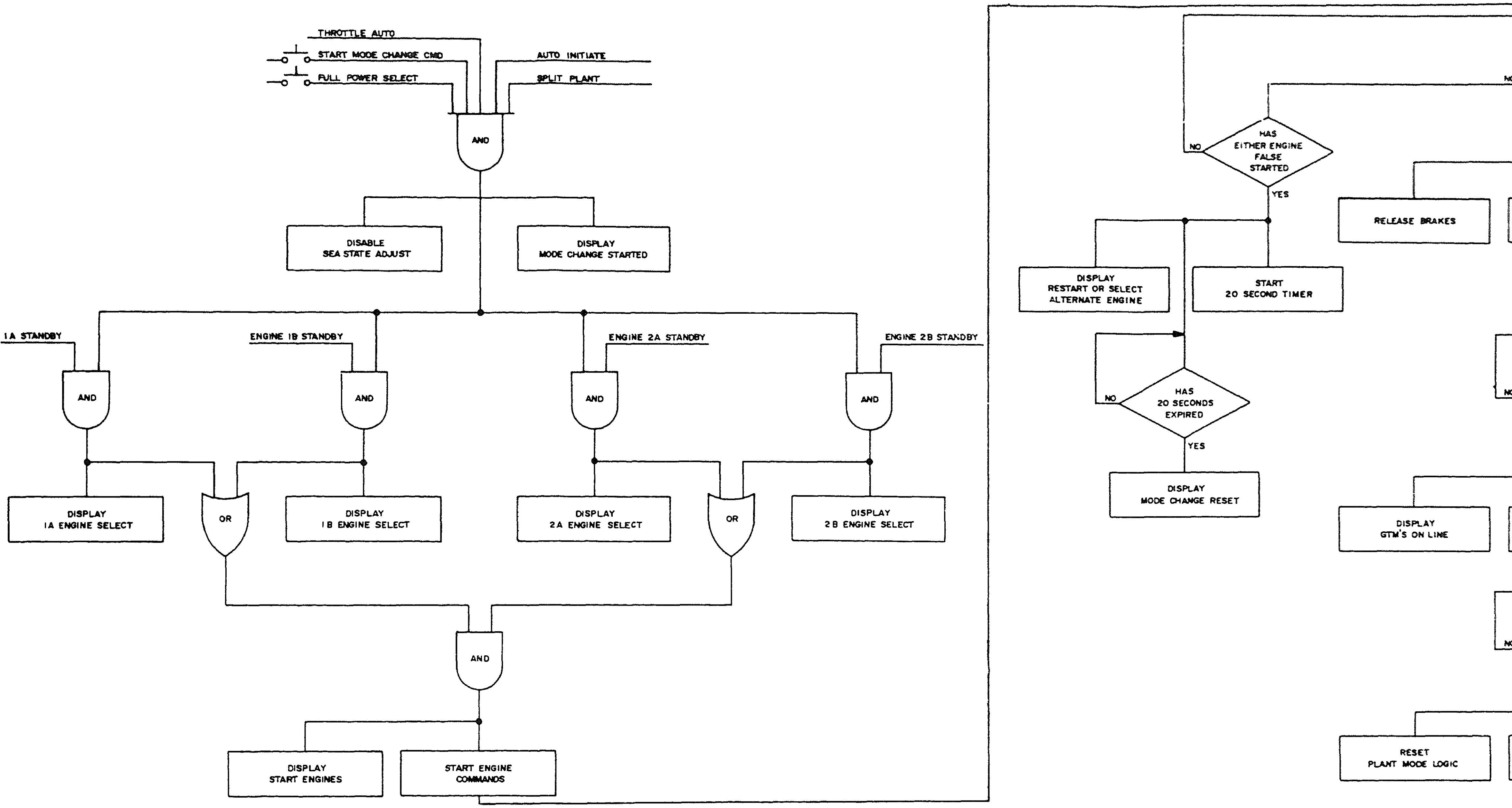

THROTTLE AUTO
START MODE CHANGE CMD
FULL POWER SELECT
AUTO INITIATE
SPLIT PLANT
AND
DISABLE SEA STATE ADJUST
DISPLAY MODE CHANGE STARTED
1A STANDBY
ENGINE 1B STANDBY
ENGINE 2A STANDBY
ENGINE 2B STANDBY
AND
OR
DISPLAY 1A ENGINE SELECT
DISPLAY 1B ENGINE SELECT
DISPLAY 2A ENGINE SELECT
DISPLAY 2B ENGINE SELECT
DISPLAY START ENGINES
START ENGINE COMMANDS
HAS EITHER ENGINE FALSE STARTED
NO
YES
DISPLAY RESTART OR SELECT ALTERNATE ENGINE
START 20 SECOND TIMER
HAS 20 SECONDS EXPIRED
DISPLAY MODE CHANGE RESET
RELEASE BRAKES
DISPLAY GTM'S ON LINE
RESET PLANT MODE LOGIC

Figure 9-1

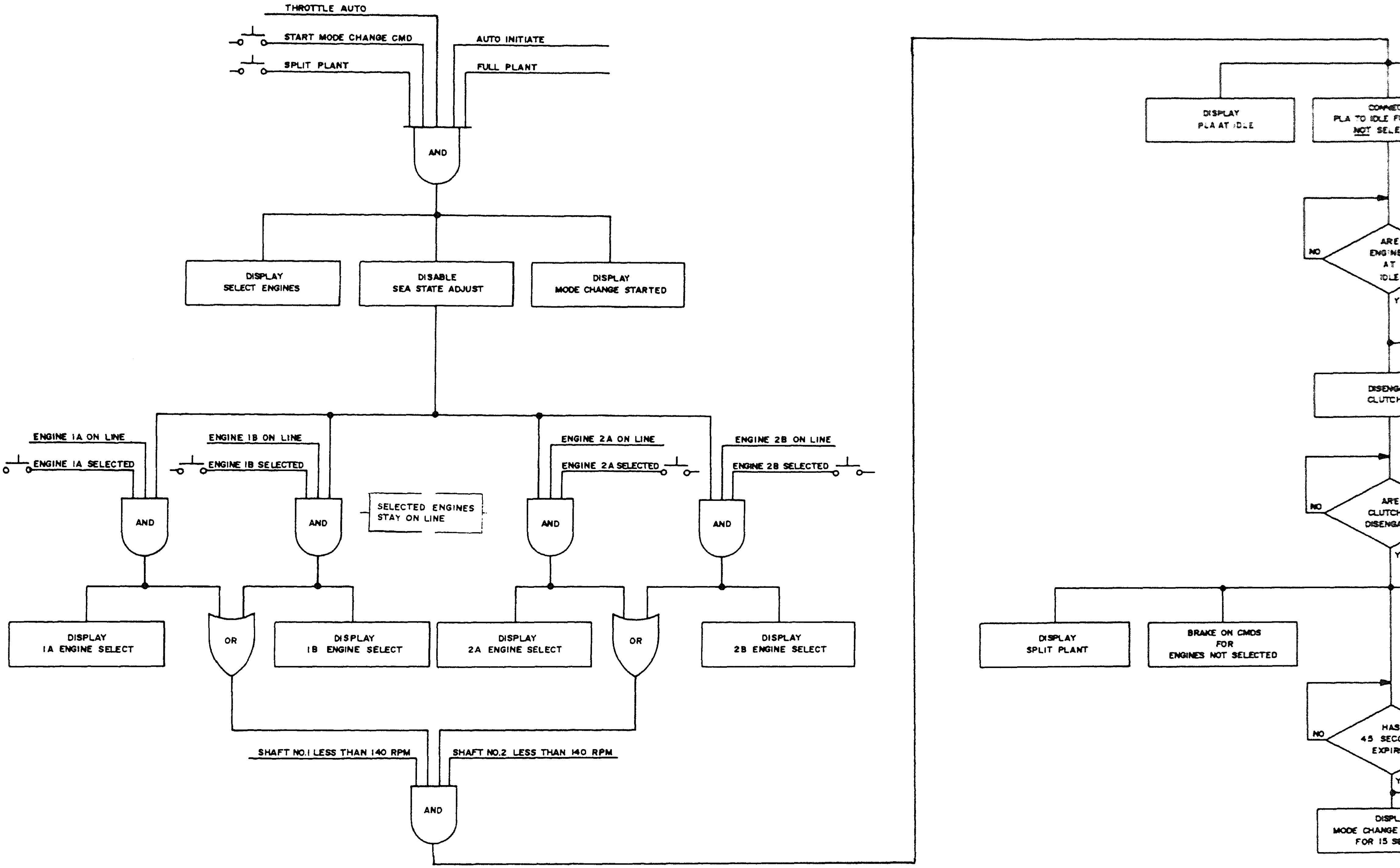


Figure 9-18.—Full

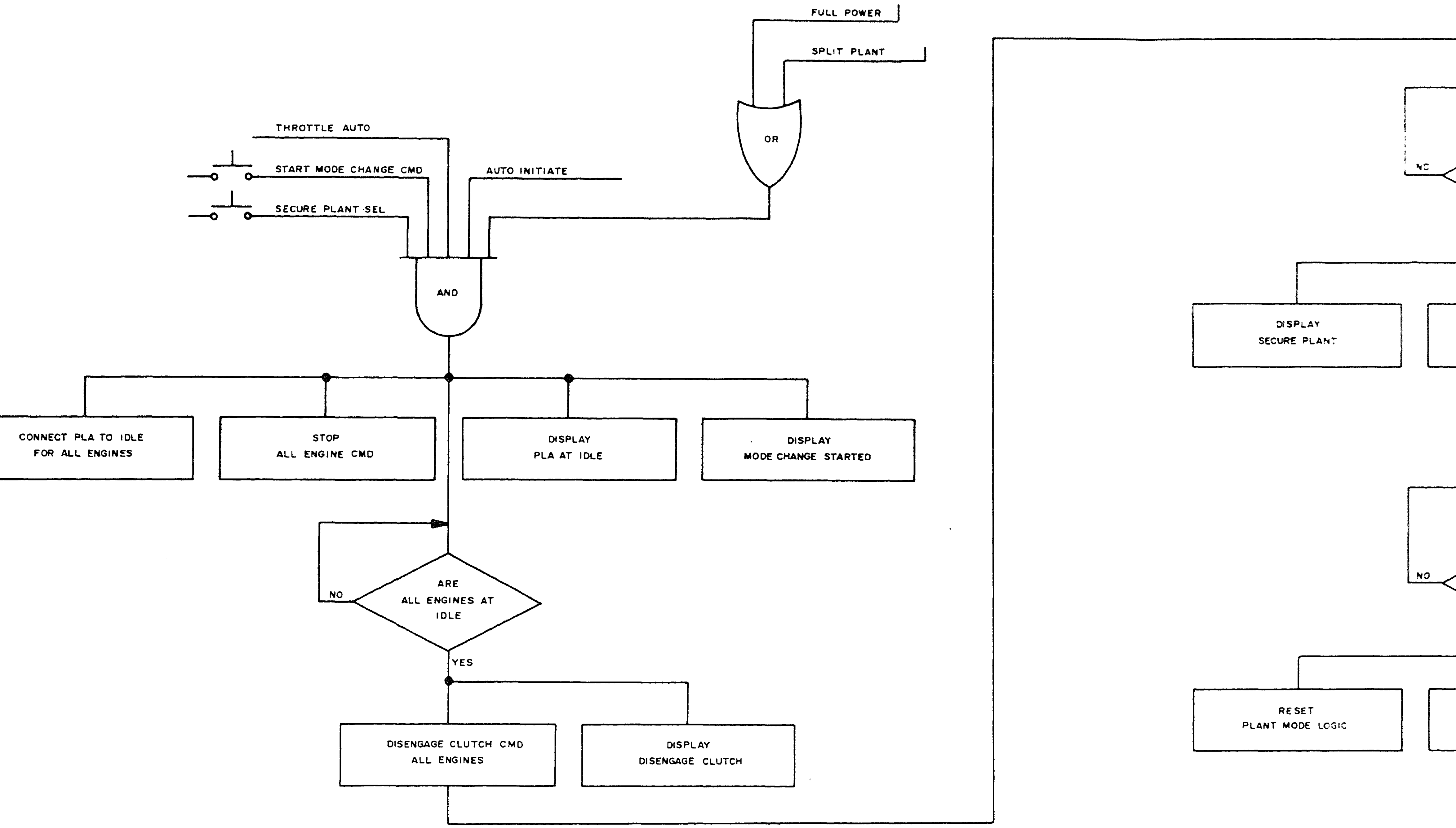


Figure 9-20.—Full

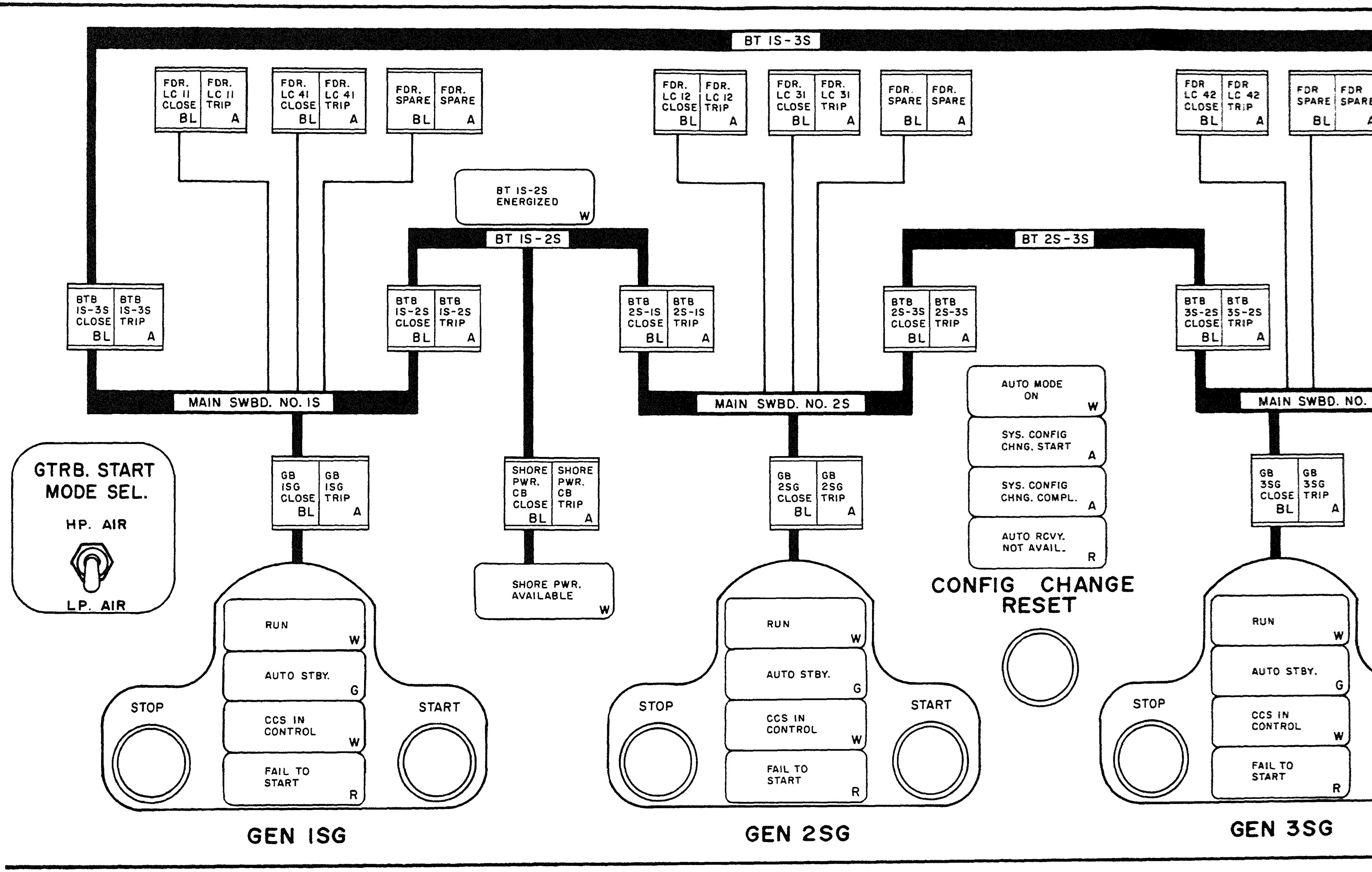


Figure 9-23.—EPCC—MIMIC panel.

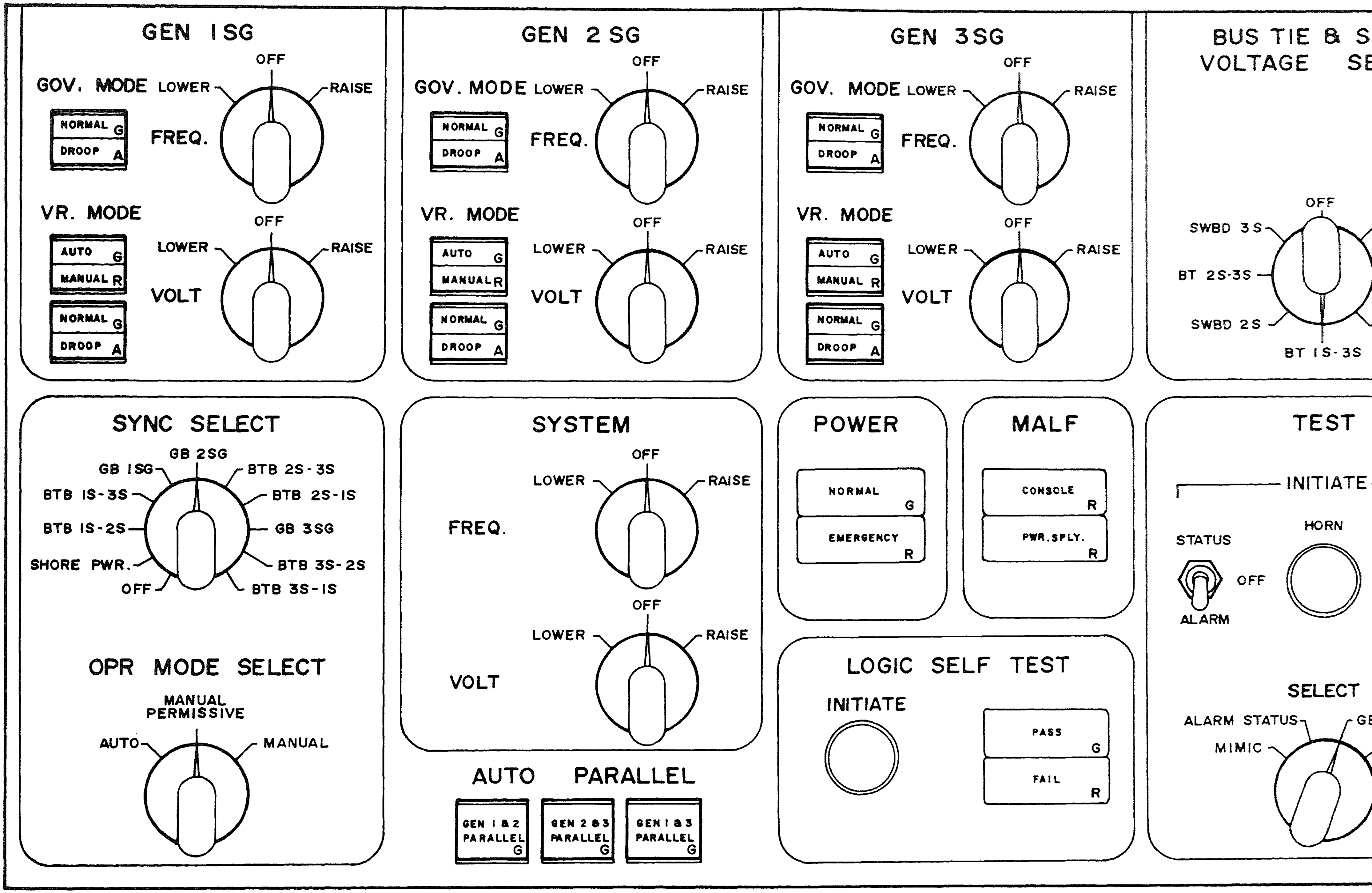
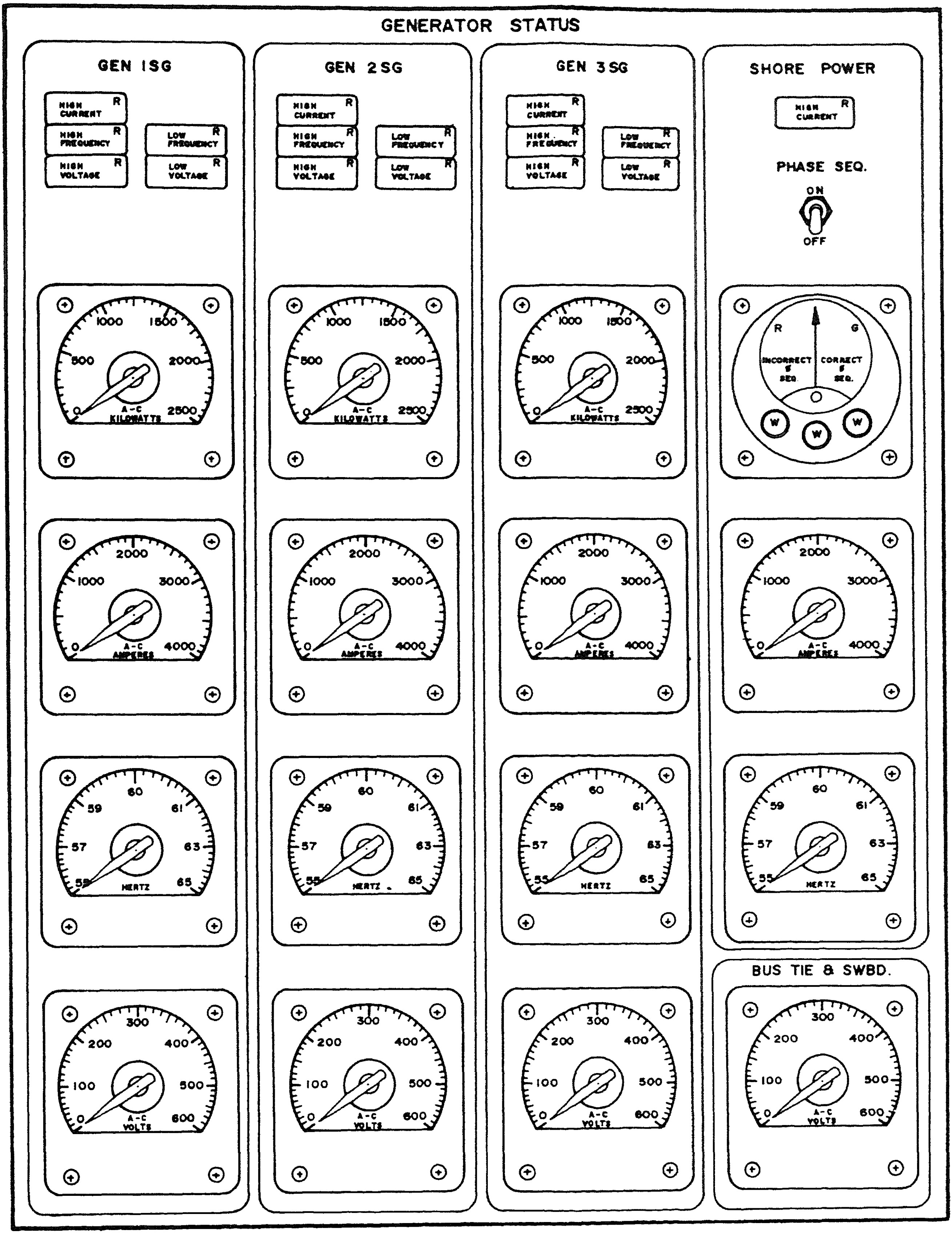
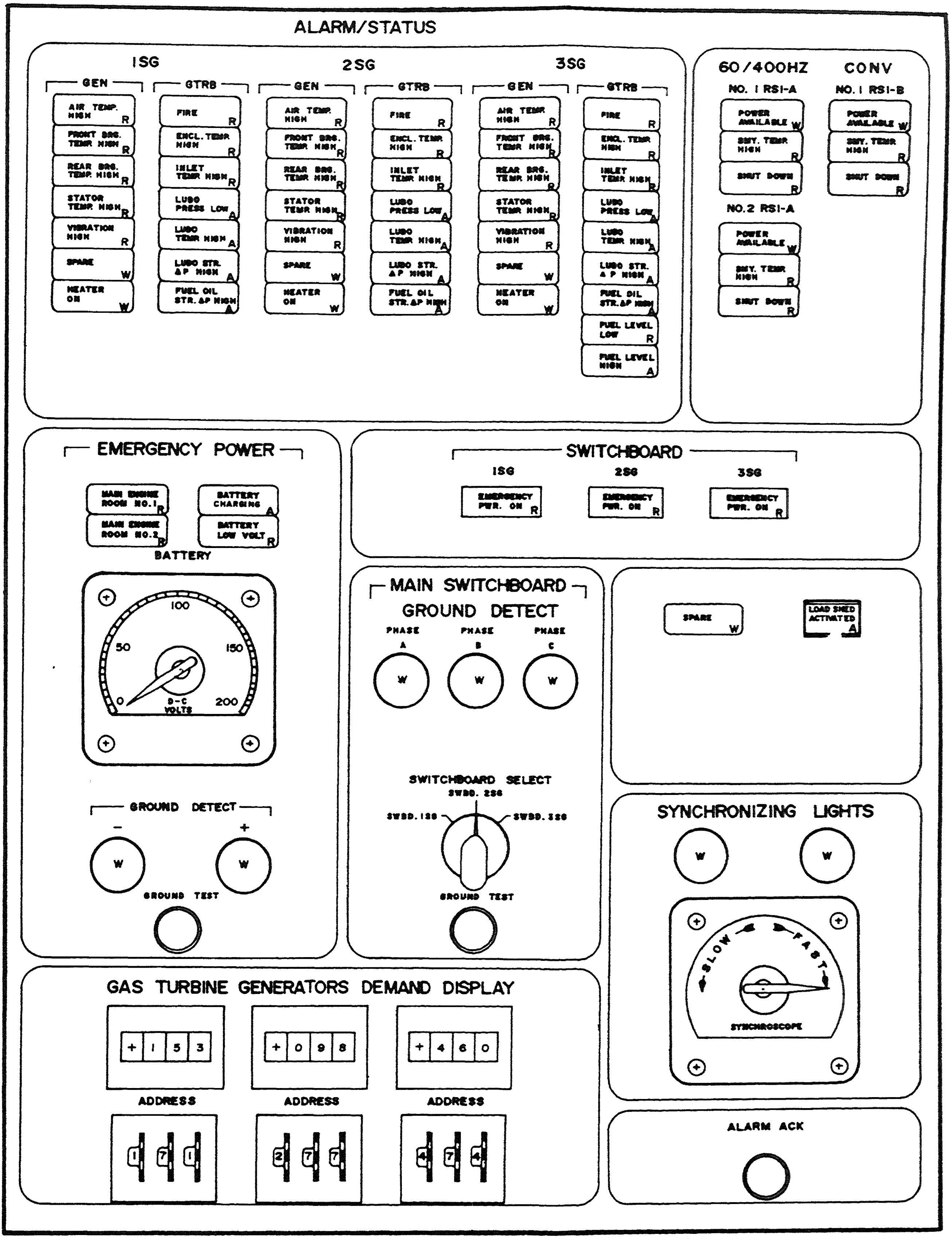


Figure 9-24.—EPCC—system control panel.



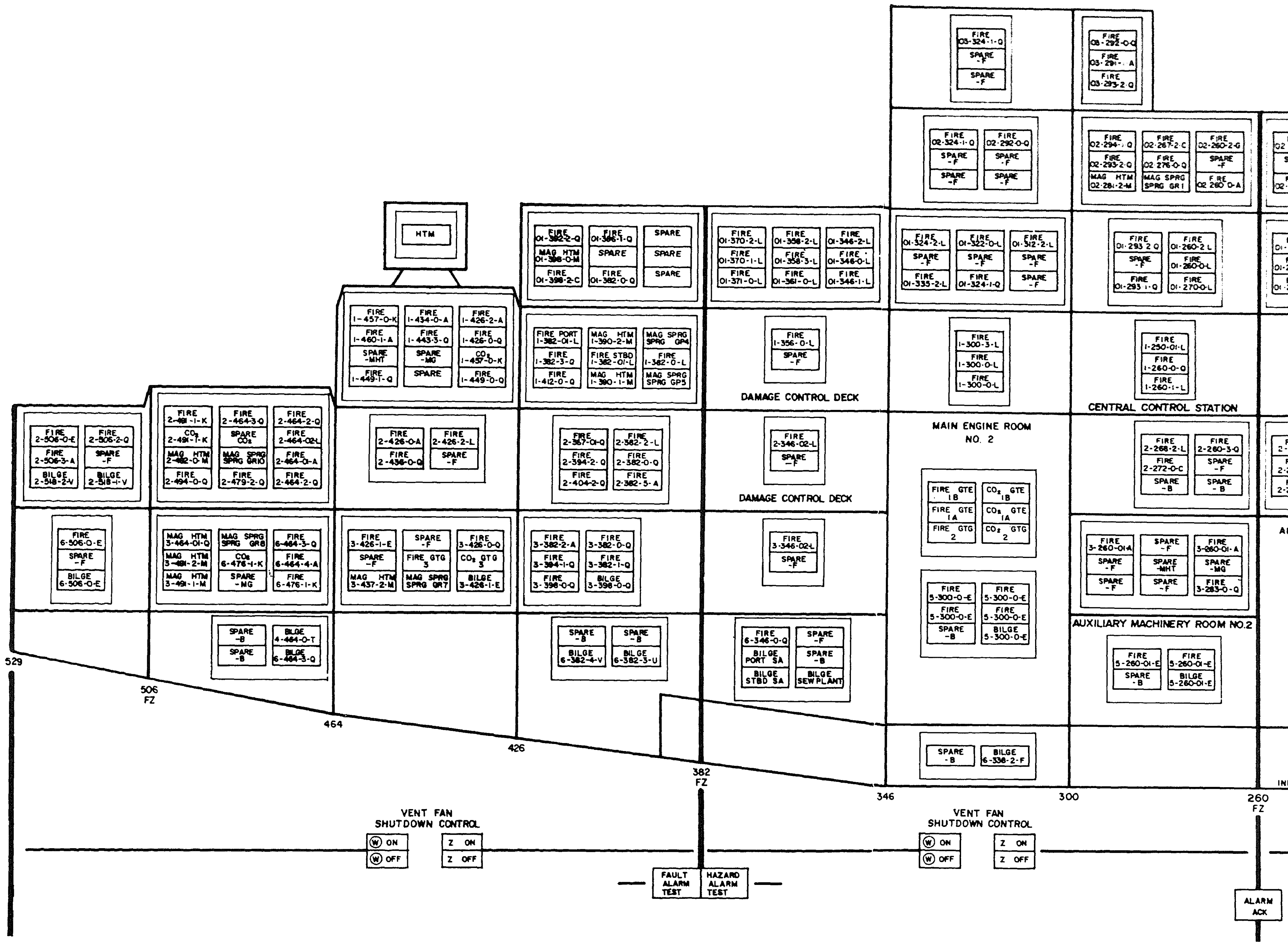
286.13

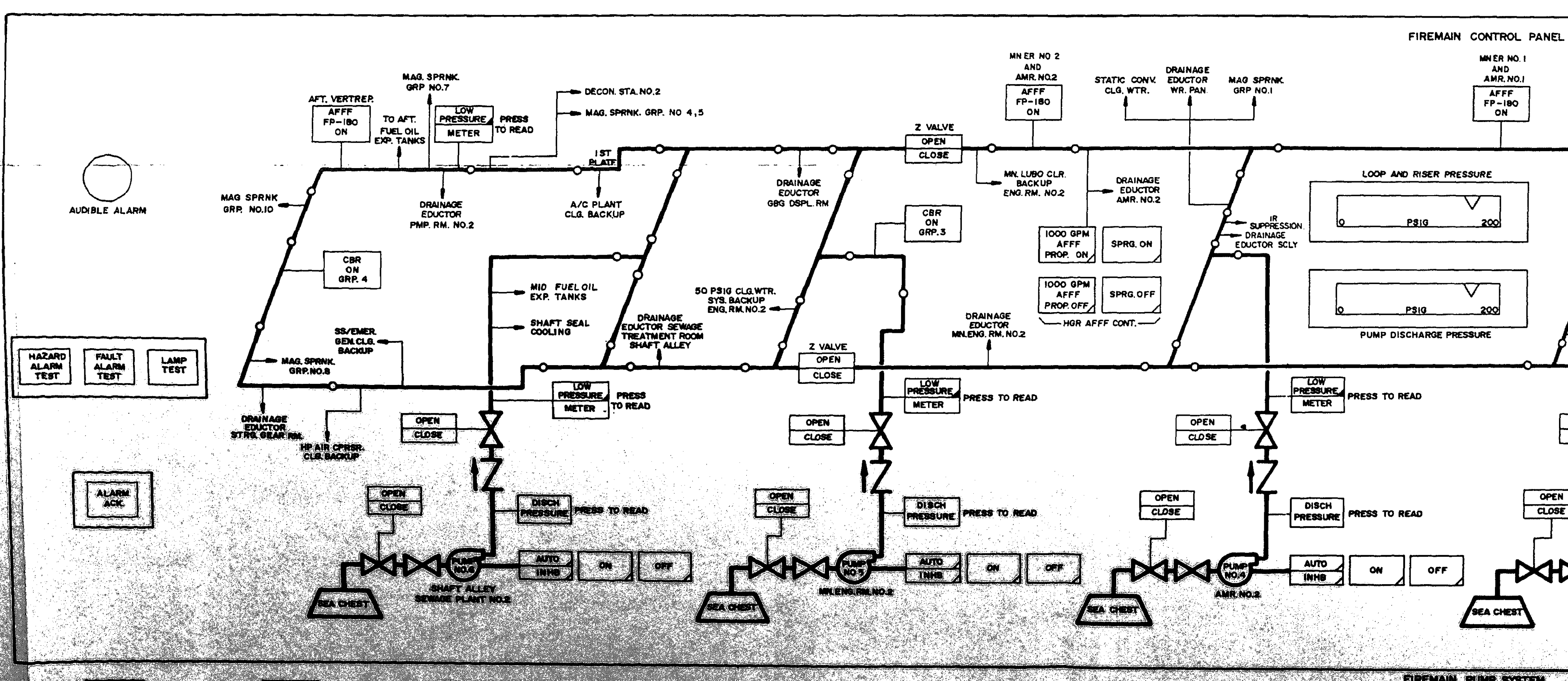
Figure 9-25.—EPCC—generator status panel.



286.14

Figure 9-26.—EPCC—alarm/status panel.


HTM
DAMAGE CONTROL DECK
DAMAGE CONTROL DECK
MAIN ENGINE ROOM NO. 2
CENTRAL CONTROL STATION
AUXILIARY MACHINERY ROOM NO.2
529
506 FZ
464
426
382 FZ
346
300
260 FZ
VENT FAN SHUTDOWN CONTROL
W ON
W OFF
Z ON
Z OFF
FAULT ALARM TEST
HAZARD ALARM TEST
ALARM ACK


FIREMAIN CONTROL PANEL
AUDIBLE ALARM
HAZARD ALARM TEST
FAULT ALARM TEST
LAMP TEST
ALARM ACK
AFT. VERTREP AFFF FP-180 ON
MAG. SPRNK. GRP. NO.7
LOW PRESSURE METER
PRESS TO READ
DECON. STA. NO.2
MAG. SPRNK. GRP. NO 4,5
Z VALVE OPEN CLOSE
MN ER NO 2 AND AMR NO.2 AFFF FP-180 ON
STATIC CONV. CLG. WTR.
DRAINAGE EDUCTOR WR. PAN
MAG SPRNK. GRP NO.1
MN ER NO. 1 AND AMR NO.1 AFFF FP-180 ON
LOOP AND RISER PRESSURE
PSIG
PUMP DISCHARGE PRESSURE
CBR ON GRP. 4
CBR ON GRP. 3
1000 GPM AFFF PROP. ON
1000 GPM AFFF PROP. OFF
SPRG. ON
SPRG. OFF
HGR AFFF CONT.
DISCH PRESSURE
PRESS TO READ
AUTO INHB
ON
OFF
SEA CHEST
SHAFT ALLEY SEWAGE PLANT NO.2
MN.ENG.RM.NO.2
AMR. NO.2
ALARM
CONTROL
STATUS
FIREMAIN PUMP SYSTEM

CHAPTER 10

CENTRAL CONTROL STATION OPERATIONS (OLIVER HAZARD PERRY CLASS)

GSEs on *Oliver Hazard Perry* (FFG-7) class ships, like those on the *Spruance* class, stand a majority of their watches in the central control station (CCS). The watches in the CCS are responsible for operating and monitoring the ship's engineering plant. To stand these watches, you must be familiar with the operation of the equipment in the CCS. This equipment includes the:

- propulsion control console (PCC),
- damage control console (DCC),
- electric plant control console (EPCC),
- auxiliary control console (ACC), and
- bell and data loggers.

This equipment allows the number of watch standers for the entire engineering plant to be kept to a minimum. Alarms and status indicators keep the CCS operators aware of plant conditions; digital displays and meters show them the vital parameters; and switches and pushbuttons allow them control of the equipment.

Just knowing where the lights, pushbuttons, and switches are located is not enough. You must also know the operation of the entire plant. Without operational knowledge of the plant, pushing the wrong pushbutton could endanger equipment, ships' maneuverability, or personnel.

After reading this chapter, you should be familiar with the operation of the equipment in the CCS and how it relates to the engineering plant. We will refer to information covered in chapters 6 and 7 as we discuss the engine-room operation and start sequence of the LM2500.

Like other material in this RTM, this chapter is designed only to familiarize you with the equipment. Use the EOSS and the Personnel Qualification Standard (PQS) to qualify on any watch station.

After reading this chapter and completing the associated NRCC, you should be familiar with the equipment in an FFG-7 CCS. You should have gained enough knowledge to start qualifying on the individual consoles in the CCS. You should also be familiar with the operation of the FFG-7 engineering plant. You may not be assigned to an FFG-7 class ship. However, this chapter should familiarize you enough with the equipment to help you advance in rate. As you become more senior in the GS rating, you may be assigned to an FFG-7 class ship. Then, this indoctrination could be helpful in beginning your qualifications.

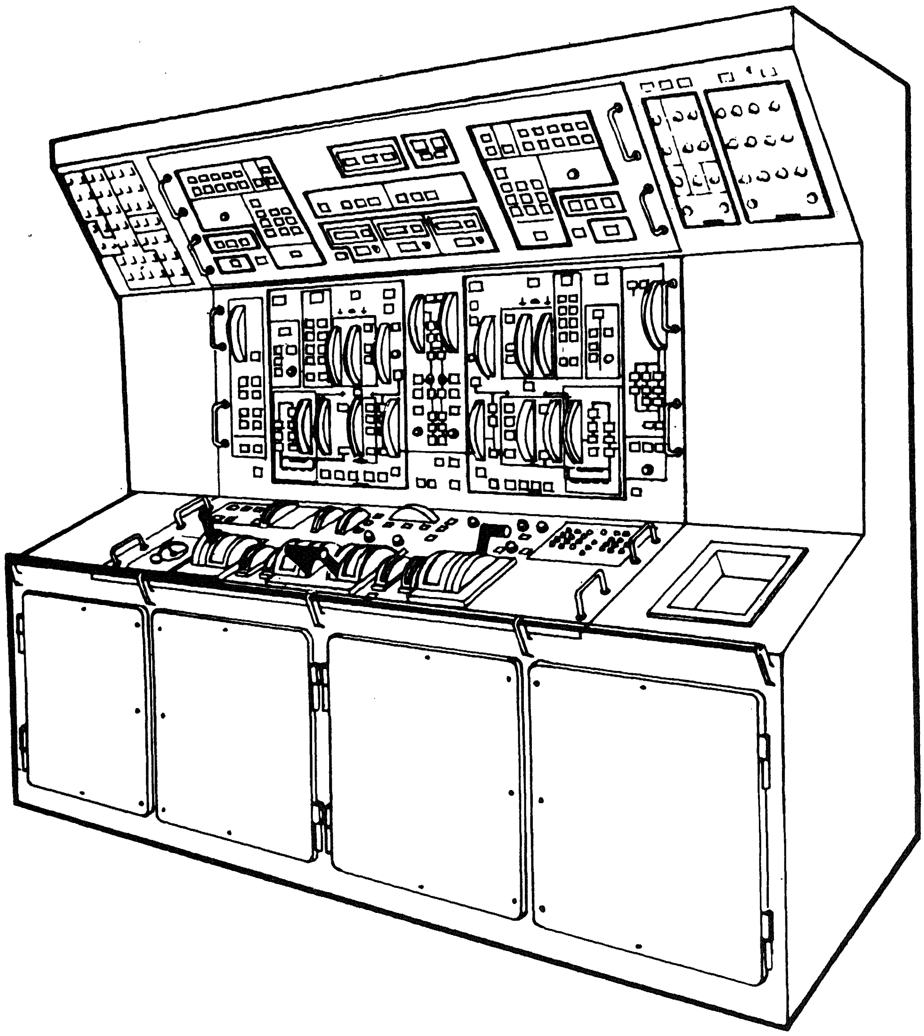
PROPULSION CONTROL CONSOLE

The PCC (figure 10-1) is the console normally used to operate the ship's main engines and propulsion equipment. It is the largest component of the propulsion control system (PCS). The PCC provides all the controls and indicators necessary to start and shut down the ship's propulsion system and its related auxiliaries.

PCC CONTROL MODES

The PCC is used to control the operation of the propulsion system in the programmed control mode or the remote manual control mode.

The programmed control mode is the primary mode for controlling the propulsion system. In this mode the operator controls a single lever. This lever provides an input to a processor. The



227.34.1

Figure 10-1.—Propulsion control console.

processor, in turn, sets the pitch of the propeller blades and the speed of the gas turbine(s).

Two modes of operation are used in the programmed mode, power control or speed control. In the power control mode, the pitch of the propeller is set to maximum. The engines are operated at their lowest possible speeds. The power mode is an open loop, temperature compensated mode using the torque computer in the FSEE to maintain constant engine loading. Power control is also used for low-noise operations. When better maneuvering response is needed, the throttle is operated in the speed control mode. In this mode the ship's speed is changed by changing the propeller pitch up to maximum with shaft rpm remaining constant. In the speed mode, shaft rpm remains constant while built-in power schedules of the program vary engine speed. The speed mode is also called closed loop, constant shaft speed mode.

Do not use the programmed control mode when the pitch of the propeller is being set from the oil injection box or when pitch is locked at full ahead. The reason for this is that the processor does not know when the pitch is operated manually or is locked. Because of this, the

processor would continue computing and transmitting propeller pitch commands, resulting in damage to the equipment.

The remote manual mode at the PCC is used when a gas turbine is started from the PCC. It is also an alternate method of operating the propulsion equipment. This method requires the operation of three levers, for propeller pitch and the speed of each gas turbine. Normally, a combination of programmed control and remote manual control is used only when engines are started or stopped, when maintenance is performed, or when damage has occurred. When one engine is in programmed control and the other is in remote manual, the pitch is controlled by the programmed control lever. The remote manual pitch lever is inoperative.

GAS TURBINE STARTING AND STOPPING

You can start a gas turbine from the PCC in the automatic or manual mode. In the automatic mode, the operator initiates the start at the PCC. The start/stop sequencer (chapter 7) in the FSEE will start the engine. The sequencer also provides the status indications for the operator to follow the start sequence. Automatic starting is inhibited if the prestart permissives have not been met and the READY TO START indicator at the PCC is extinguished.

Manual starts from the PCC require the operator to activate circuits and sequence the start manually. The start/stop sequencer provides status indications of the start sequence to the operator. Again, the start/stop sequencer prohibits start until the prestart permissives have been met and the READY TO START indicator on the PCC start panel is illuminated.

You can shut down the gas turbine by four modes. Three are operator selectable from the PCC. The modes of stopping are as follows.

- Normal stop—operator initiated
- Manual stop—operator performed
- Emergency stop—operator performed
- Automatic shutdown—logic initiated

Normal stops are performed in the remote manual mode. The operator, following the EOSS, must bring the engine to idle. Depressing the normal stop pushbutton initiates a normal stop sequence, performed by the start/stop sequencer. This causes the engine to run for 5 minutes at idle before fuel valve closure which allows the engine to cool. This cooldown period lengthens engine life.

The operator may perform manual stops from the PCC in the remote manual mode. The operator is required to sequence this stop. The engine should be allowed to run at idle for 5 minutes before the closure of the fuel-shutdown valves.

The PCC operator may activate the emergency stop at any time and in any operating mode, regardless of the console in control. The emergency stop is initiated by depressing the emergency stop pushbutton. This causes the engine's fuel valves to immediately close.

Automatic shutdowns may occur when the engine is started or running. The automatic shutdowns de-energize the fuel valves. This causes the engine to shut down. The conditions during start that cause an automatic shutdown are as follows.

- N_{GG} fails to reach 1200 rpm within 20 seconds after start is initiated.
- Failure to reach 400°F $T_{5.4}$ within 40 seconds after the fuel valves are energized.
- N_{GG} fails to reach 4500 rpm within 90 seconds after start is initiated.
- Engine lube oil pressure is below 6 psig 45 seconds after start is initiated or engine speed is above 4500 ± 200 rpm.

During engine operation, the following conditions cause an automatic shutdown.

- GG flameout—$T_{5.4}$ below 400°F with fuel manifold pressure above 50 psig
- $T_{5.4}$ above 1530°F
- N_{pt} above 3960 ± 40
- Engine lube oil pressure less than 6 psig

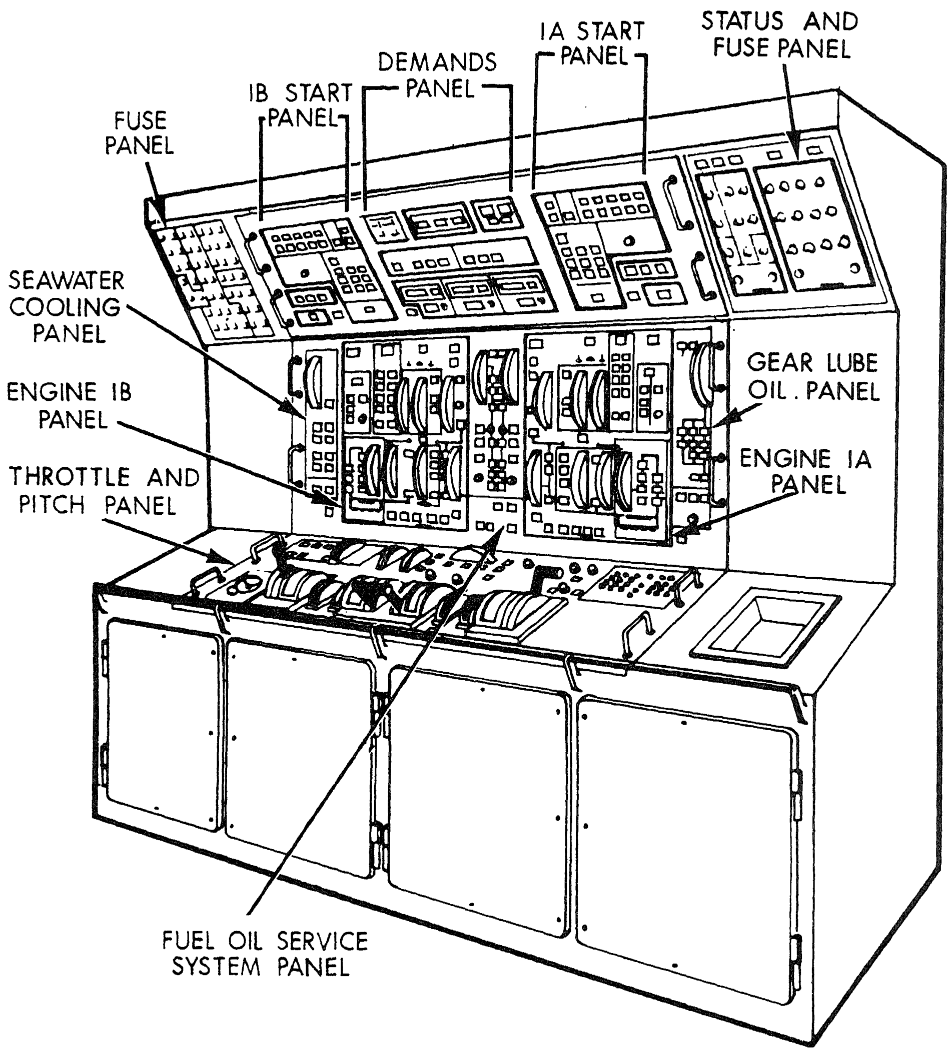
- GG vibration above 7 mils
- PT vibration above 10 mils

NOTE: Battle override inhibits all automatic shutdowns except flameout and PT overspeed.

PCC CONTROLS AND INDICATORS

The PCC is subdivided into panels (figure 10-2). In the center of the top section of the PCC is the demands panel. On either side of the demands panel are the engine start panels (1A on the right side, 1B on the left side). On the middle section of the PCC from left to right are the (1) seawater cooling panel, (2) engine 1B panel, (3) fuel oil service panel, (4) engine 1A panel, and (5) reduction gear lube oil panel. The lower section of the PCC is the propulsion panel. This panel has the throttle controls and the propeller pitch hydraulic oil panel. On the top outboard sections of the console are a fuse panel and a fuse and status panel.

Follow the related figures as we discuss the various PCC control and indicating panels. The parenthetical letters are shown on the figures.



227.34.2

Figure 10-2.—PCC panel breakdown.

Refer to these letters to find the section of a panel when it is discussed.

Demands Panel

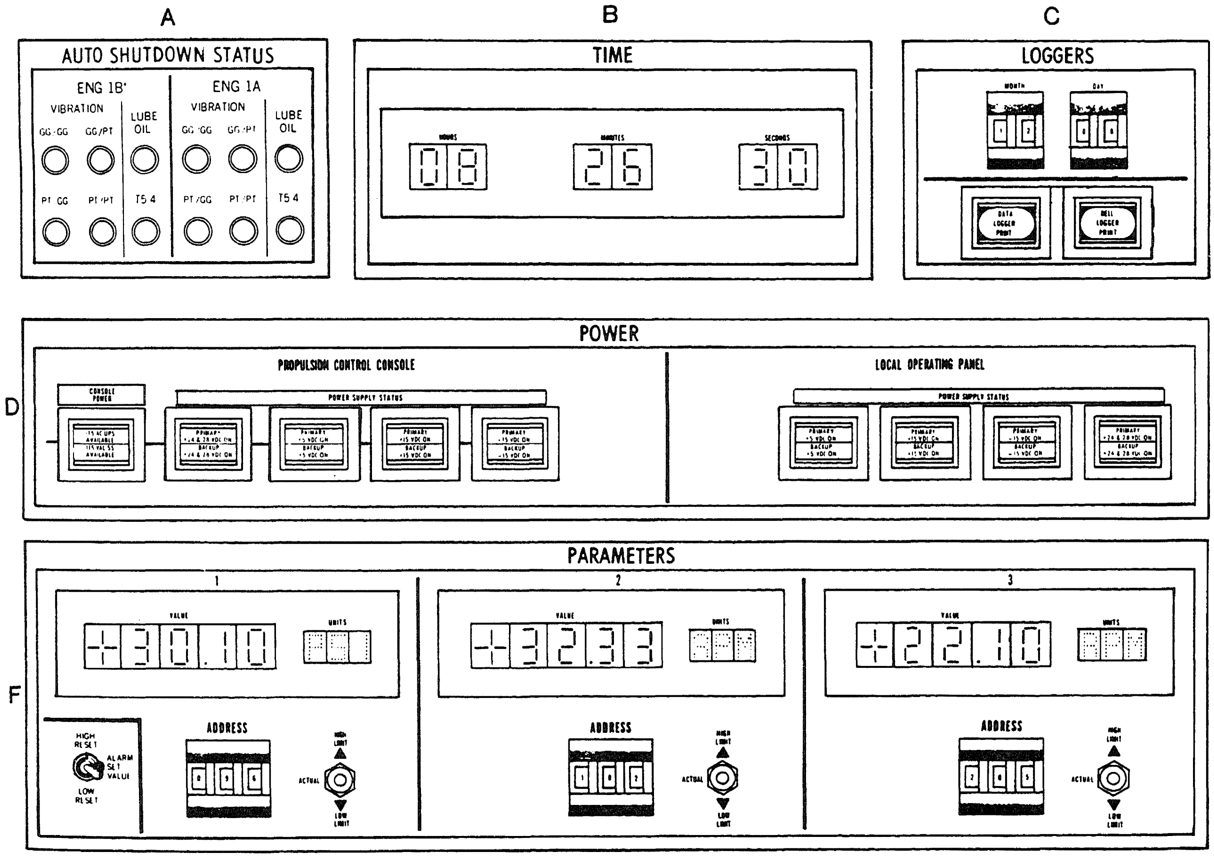
The demands panel (figure 10-3) has information and controls such as status, time, logger commands, power supply status, and selected parameter values.

AUTO SHUTDOWN STATUS.—The auto shutdown status indicators (A) illuminate red when an auto shutdown occurs, either on engine 1A or 1B. An auto shutdown may occur because of vibration, low lube oil pressure, or high $T_{5.4}$. These are reset when the automatic shutdown is reset.

TIME.—The time section (B) has a digital display using LEDs of the time generated by the PCC real-time clock.

LOGGER COMMANDS.—The logger section (C) has two sets of thumbwheels and two pushbutton switches. The thumbwheels are used to set the month and day into the processor for use on the automatic logger. These must be updated daily. The pushbuttons cause the data or bell logger to print, depending on which is selected.

POWER.—The power section (D and E) of the demands panel is divided into two sections, the propulsion control console (D) and the local operating panel (E). These two sections provide power supply status for the logic power supplies



293.116

Figure 10-3.—Demands panel.

in the PCC and LOP. They also provide console status for the PCC. These indicators are split-type and both halves are normally illuminated. If either half of an indicator is dark, check the power supplies for malfunctions.

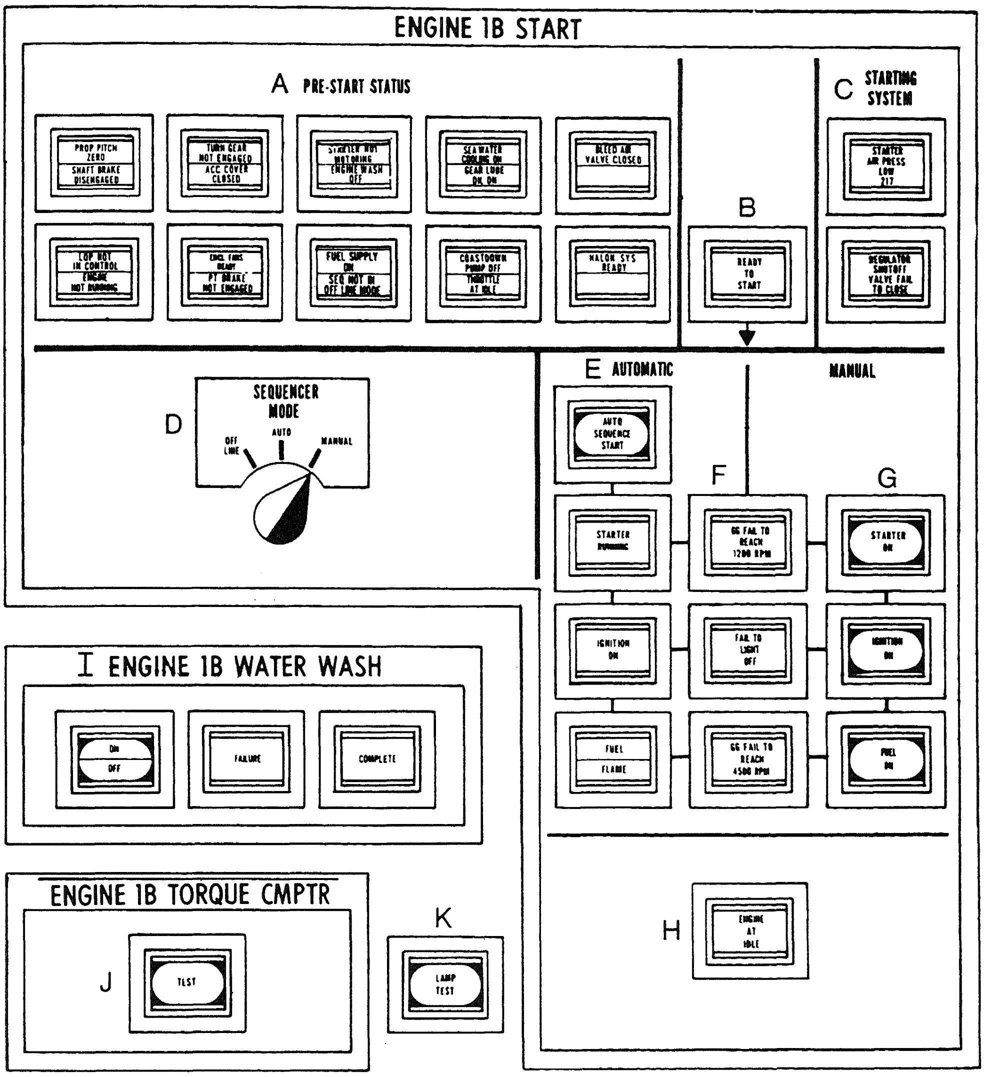
PARAMETERS.—The parameters section (F) has three digital display sections. Each contains a display, a thumbwheel, and a toggle switch. The digital displays are also found on the EPCC and the auxiliary control console (ACC). The thumbwheel is used to select an address, found on a DDI listing, that calls up the selected parameter. The parameter is displayed with the decimal in the proper position and with the units used to measure the parameter (psi, rpm, and so forth). A toggle switch is also used to display either the high-alarm limit, the actual value, or the low-alarm limit. A second toggle switch, used in conjunction with this first toggle switch, allows the operator to verify the high/low reset value of the alarm.

Engine Start Panels

The two engine start panels (figure 10-4) are mirror images of each other. They have identical pushbuttons and indicators. These indicators and controls are used to monitor or control the start of one of the gas turbines.

PRESTART STATUS.—The prestart status section (A) has ten split indicators used to display the status of components in the plant before start. There are a total of 18 indicators on this section. Starting on the top outside indicator and going across the top row, the indicators are as follows.

1. PROP PITCH ZERO	Propeller pitch is at zero (bypassed for second engine).
2. SHAFT BRAKE DISENGAGED	Shaft brake is disengaged (bypassed for second engine).
3. TURN GEAR NOT ENGAGED	The turning gear motor is not engaged to the gearbox and is not locked.
4. ACC COVER CLOSED	Clutch access doors for both engines are closed.
5. STARTER NOT MOTORING	Engine starter is not motoring (turning).
6. ENGINE WASH OFF	Engine is not being water washed.
7. SEAWATER COOLING ON	Seawater cooling pressure is greater than 7 psi, and the discharge valve is open.
8. GEAR LUBE OIL ON	MRG lube oil supply pressure is greater than 9 psi.
9. BLEED AIR VALVE CLOSED	Bleed air valve on that engine is closed.
10. LOP NOT IN CONTROL	Control of the engine is not at the LOP.
11. ENGINE NOT RUNNING	N_{GG} is less than 1200 rpm, $T_{5.4}$ is less than 400°F, and fuel manifold pressure is less than 50 psi.
12. ENCL FANS READY	Enclosure fan is ready to run depending upon automatic fan circuitry.
13. PT BRAKE NOT ENGAGED	The PT brake for that engine is not engaged.
14. FUEL SUPPLY ON	One of the two fuel tanks has more than 20%, the fuel supply cutoff valve is open, and the fuel supply pressure is greater than 8 psi.



293.117

Figure 10-4.—Engine start panel (1B shown, 1A is mirror image).

15. SEQ NOT IN OFF-LINE MODE	The sequencer mode switch is not in the off-line position.
16. COASTDOWN PUMP OFF	The coastdown pump is not running.
17. THROTTLE AT IDLE	The engine PLA is setting at the idle position.
18. HALON SYS READY	The Halon inhibit switch is not on and the Halon system is ready.

READY TO START.—The READY TO START indicator (B) only illuminates when the 18 prestart permissives have been met. The engine cannot be started in either the automatic or manual mode until this indicator is illuminated.

STARTING SYSTEM.—The starting system section (C) has two indicators used to display

abnormal conditions in the starting air system. The STARTER AIR PRESS LOW indicator illuminates when the starting air pressure drops below 35 psi as sensed by one of two pressure transducers. The REGULATOR SHUTOFF VALVE FAIL TO CLOSE indicator illuminates when the start air valve on the GT has not closed and the GG speed has reached 4900 rpm.

SEQUENCER MODE SELECTOR SWITCH.—The sequencer mode selector switch (D) is a three-position rotary switch used to determine the operating mode of the start/stop sequencer. The three modes are off-line, auto, and manual. The off-line position will prevent the engine from being started at the PCC. This mode is normally used only during maintenance, water washing, and motoring. The auto position allows the AUTO SEQUENCER START pushbutton to be used to start the engine using the start/stop sequencer. In the manual position, the operator has to start the engine using the manual pushbuttons and do the sequencing.

START SEQUENCING.—The start sequencing section (E, F, G, and H) has ten pushbuttons and indicators used to control or monitor the engine start. The automatic start section (E) has a pushbutton and three indicators used to start the engine in the automatic mode. The AUTO SEQUENCE START pushbutton is depressed to initiate the auto start sequence in the start/stop sequencer. This action will only start the sequence if the sequencer mode select switch (D) is in AUTO, and the READY TO START indicator (B) is illuminated. The first indicator to illuminate during an auto start sequence is the STARTER RUNNING indicator. This shows the starter regulator/shutoff valve is open. The next indication is for IGNITION ON. This indicator shows that the igniters are energized through the start/stop sequencer. The third indicator is a split-type that reads FUEL/FLAME. The FUEL indicator illuminates when the fuel manifold pressure is greater than 50 psi. The FLAME indicator illuminates when $P_{t5.4}$ is greater than 400 °F.

The three center indicators (F) are used to show out-of-tolerance conditions during an engine start. These three conditions will also cause an automatic shutdown. These indicators illuminate when (1) N_{GG} FAILS TO REACH 1200 RPM, (2) the engine FAILS TO LIGHT OFF, or (3) N_{GG} FAILS TO REACH 4500 RPM. The parameters for these alarms were detailed earlier.

The three manual start pushbuttons (G) are used to manually sequence the start/stop sequencer during a manual start. The pushbuttons are labeled STARTER ON, IGNITION ON, and FUEL ON. These pushbuttons are used when the sequencer mode selector switch (D) is in the MANUAL or OFF-LINE mode. The STARTER ON pushbutton, when depressed, opens the starter shutoff/regulator valve. Depressing it again will close the valve, although it will automatically close at 4500 rpm (N_{GG}). The IGNITION ON pushbutton is a momentary pushbutton switch. When this pushbutton is depressed, it energizes the igniters. It de-energizes them when it is released. The FUEL ON pushbutton is also a momentary-type switch. Depressing it causes the fuel valves to open. During a start, these valves are latched open by the sequencer.

The ENGINE AT IDLE lamp (H) is illuminated when N_{GG} is between 4900 and 5000 rpm.

WATER WASH.—The engine water wash section (I) has one split-legend latching-type pushbutton switch and two indicators. The ON/OFF indicator switch is enabled (1) when the water wash control is in REMOTE at the engine room controller, (2) the sequencer mode switch on the PCC is in the OFF-LINE position, and (3) the engine control mode switch is in the PROGRAMMED position. When these conditions have been met, depressing the ON/OFF switch signals the processor to start the engine wash sequence. FAILURE, an alarm indicator, illuminates if any of the following conditions occur: (1) initially if the wash and the rinse tanks are not full, (2) if once the wash cycle has started and the wash tank is not empty within 4 minutes, and (3) if the rinse tank is not empty within 10 minutes. The COMPLETE indicator illuminates when the automatic engine wash cycle has been completed.

TORQUE COMPUTER.—The torque computer TEST pushbutton/indicator (J) is used to perform a confidence check of the engine torque computer. When this pushbutton is depressed, it

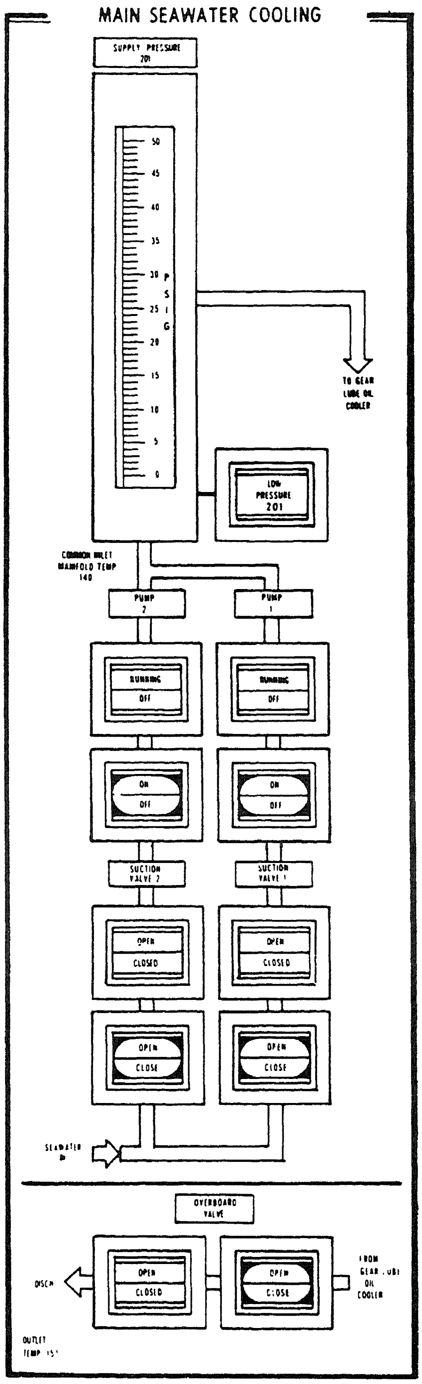
"plugs in" a set of fixed values that replace the normal engine parameters to calculate the engine's torque and horsepower. These calculated values are then compared to fixed reference values in the FSEE. If the result is correct, the TEST pushbutton/indicator illuminates by a "test passed" signal from the FSEE. If it does not illuminate, the torque computer is not working correctly. This test should only be done when the engine is secured or at idle. This is because the normal engine parameters are being replaced with a fixed set of parameters and there is no overtorque protection during this time.

LAMP TEST.—The LAMP TEST (K) pushbutton is used to check the condition of the lamps. When it is depressed, all the indicators and switches on the panel should illuminate, except the heater indicator.

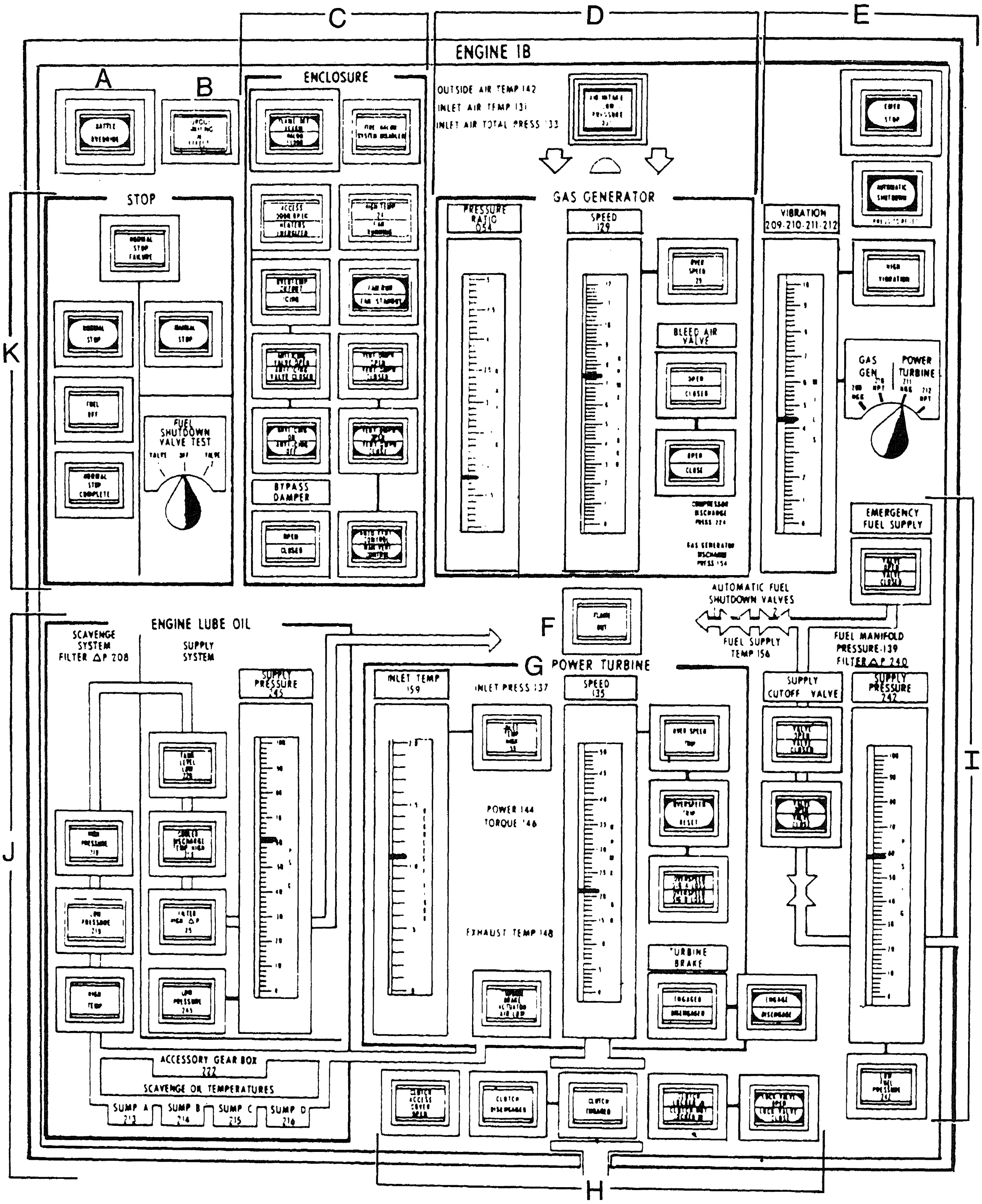
Main Seawater Cooling Panel

The main seawater cooling panel (figure 10-5) is located on the left side of the middle panel of the PCC. It is used to control and monitor the operation of the engine-room main seawater system. This system is used to cool the reduction gear lube oil. The control available from this panel allows opening and closing of three valves and start/stop control of two pumps. The three valves controlled from the PCC are pump 1A suction valve, pump 1B suction valve, and the overboard discharge valve. (NOTE: The panel is labeled for pump and suction valves 1 and 2. Pump 1 controls 1A pump and suction valve 1 controls 1A suction valve. Pump 2 controls 1B pump and suction valve 2 controls 1B suction valve.) Each valve has an OPEN/CLOSE pushbutton to operate the valve and an OPEN/CLOSED indicator to show actual valve status. Also, each pump has an ON/OFF pushbutton to start and stop the pump as well as a RUNNING/OFF indicator to show the status of the pump.

A LOW PRESSURE alarm and a supply pressure meter are used to monitor main seawater cooling pressure. Normal pressure is 30 to 35 psig. The low seawater alarm will sound at 7 psig with a 10-second delay.



293.118
Figure 10-5.—Main seawater cooling panel.



293.119

Figure 10-6.—Engine 1B panel (engine 1A panel is a mirror image).

Engine Panel

The PCC engine panel (figure 10-6) has many of the same controls and indicators found on the LOP. It contains the controls, indicators, and meters needed to remotely operate the GTs. The engine 1A and 1B panels are mirror images of each other. We will cover the engine 1B panel in our discussion; keep in mind that the 1A panel has identical features.

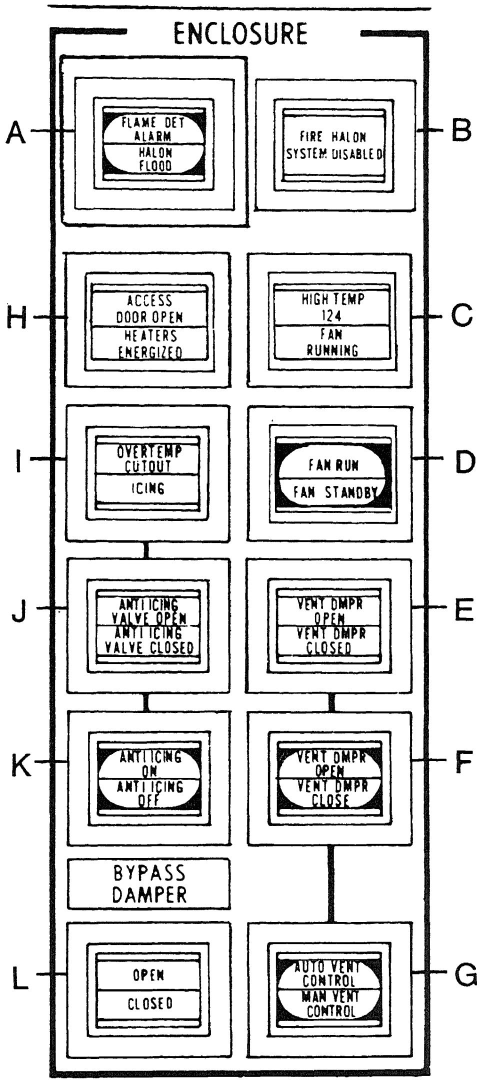
BATTLE OVERRIDE.—BATTLE OVERRIDE (A) is a guarded, illuminated pushbutton. You can use it only if the PCC is the station in control. It is illuminated when on. This switch overrides the following shutdowns.

1. GTM low lube oil pressure
2. High engine vibration
3. High $T_{5.4}$
4. Power lever angle failure for:
   a. PCS command signal out of limits
   b. PT shaft torque out of limits
   c. PT speed out of limits

It does not override a flameout or a PT overspeed trip.

TORQUE LIMITING IN EFFECT.—The TORQUE LIMITING IN EFFECT indicator (B) illuminates any time the torque limiting circuit is restricting the advancing of the PLA. This is done until the torque on the engine is within safe limits. Then the torque limiting circuit will allow the PLA to advance to the command position, provided the PLA doesn't send the engine into an overtorque condition. If it does, then the torque limiting circuit will take over again as before. This will continue until the command is obtained, or the command is reduced to a lower setting.

ENCLOSURE.—The location of the enclosure section (C) on the engine 1B panel is shown in figure 10-6. Figure 10-7 is an enlarged view of this section. The following paragraphs describe the switch/indicators of the enclosure section. The first switch/indicator (A) is located on the top left-hand side of the enclosure section. It is a split indicator. The upper half is FLAME DET ALARM. When it is illuminated, the UV sensor has sensed a flame in the enclosure. The



293.120

Figure 10-7.—Enclosure section of an engine panel.

lower half, HALON FLOOD, is the switch. Depressing this switch releases the primary bank of Halon. This occurs if the manual inhibit switch is in the active position at the enclosure. NOTE: There is no automatic release of Halon into the enclosure.

The FIRE/HALON SYSTEM DISABLED indicator (B) is next to the FLAME DET ALARM indicator. It is illuminated when a loss of continuity in the fire or the Halon system occurs. This is caused by loss of continuity between the flame

detector and signal conditioner or loss of 115-volt a.c. power to the detection system. Power is supplied by the 115-volt a.c. CB in the FSEE.

The next indicator down is a split-legend indicator (C). The upper half, HIGH TEMP, is the indicator being fed from the two temperature switches (set at 400 °F) in the enclosure. The lower half, FAN RUNNING, is illuminated when the enclosure fan is running.

The next indicator down (D) is a switch/indicator, FAN RUN/FAN STANDBY. It selects the mode of operation for the ventilation fan. In the FAN RUN position, the fan will be running. In the FAN STANDBY position, the fan automatically starts when:

- the engine is running below 3000 hp; or
- the engine is not running and the enclosure temperature is above 125 °F.

The fan automatically shuts down when:

- Halon is discharged into the enclosure;
- the engine is running above 3000 hp;
- the engine is not running and the enclosure temperature is below 125 °F; or
- the vent damper closes.

To start a gas turbine engine, the fan controller must be in the remote position and the control on the PCC should be in the standby position.

The last three indicators down (E, F, and G) are for the vent damper. The VENT DMPR OPEN/VENT DMPR CLOSED indicator (E) shows the position of the vent damper. The VENT DMPR OPEN/VENT DMPR CLOSE switch/indicator (F) is for manual control. It is only functional when the AUTO VENT CONTROL/MAN VENT CONTROL switch/indicator (G) is in the MAN VENT CONTROL position.

The AUTO VENT CONTROL/MAN VENT CONTROL switch/indicator is used to select the mode of operation for the ventilation damper, either automatic or manual. In automatic mode, the ventilation damper will open when:

- the ventilation fan is running;
- the engine is running; or
- the engine is not running and the outside air temperature is above 70 °F.

The damper will close automatically when:

- Halon is discharged into the enclosure; or
- the engine is not running and the outside air temperature is below 70 °F.

In the manual mode, damper control circuits automatically close the damper if Halon is discharged into the enclosure.

At the top of the next column is the ACCESS DOOR OPEN/HEATERS ENERGIZED indicator (H). The upper half is fed from switches at the two doors. The fuel/enclosure heater keeps the enclosure air temperature above 60 °F. This temperature is required to prevent fuel waxing (fuel hardening) in the engine fuel system. The ceiling-mounted heater is a forced air space heater rated at 8 kW. The heater is electrically powered and thermostatically controlled. It is energized when the inlet air temperature is 60 ° to 70 °F. It is de-energized when the temperature reaches 85 ° to 90 °F. Overtemperature protection and a manual reset are provided. Air circulation is provided by a blower when temperatures are below 125 °F. Blower operation stops when the temperature reaches 145 °F. Control of the heater is provided on the LOP. Indication of the heater status is provided on both the PCC and the LOP.

The OVERTEMP CUTOUT indicator (I) will illuminate when the heater is de-energized because the enclosure temperature was 145 °F and the heater was on.

The ICING detector indicator (I) measures the temperature and humidity of the incoming combustion air. When icing conditions occur, temperature below 41 °F and humidity above 70 percent, an alarm is provided at the PCC.

The ANTI-ICING VALVE OPEN/ANTI-ICING VALVE CLOSED indicator (J) shows the actual position of the anti-icing valve. Below this indicator is the ANTI-ICING ON/ANTI-ICING OFF control switch/indicator (K). It is used to control the anti-icing valve.

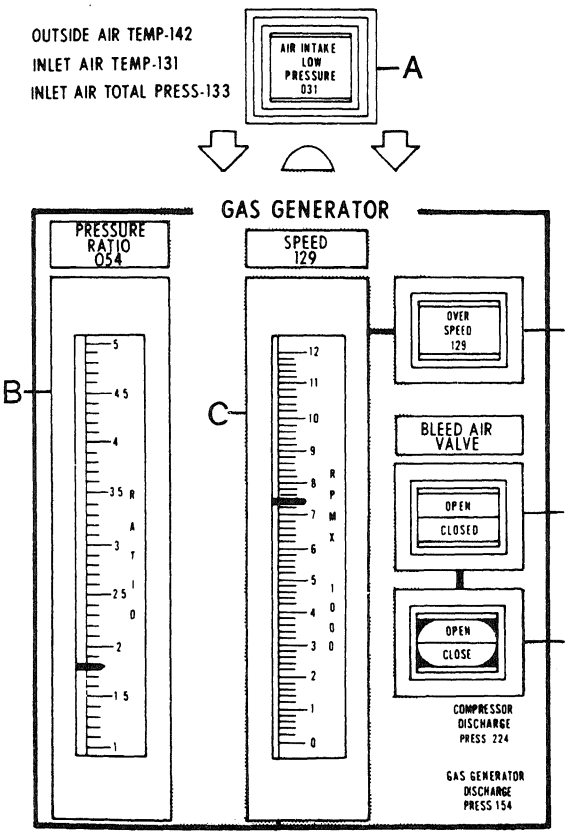
The last indicator in this section is the BYPASS DAMPER. The bypass damper, mounted in the cooling air bypass intake trunk, opens to provide an air path from the atmosphere to the GT enclosure; it closes to prevent the reverse flow of air through the bypass intake trunk when the cooling fan is running. Switches at the bypass damper provide signals to the PCS to show the

OPEN/CLOSED status (L) of the bypass damper at the PCC.

GAS GENERATOR.—The location of the GG section (D) on the engine 1B panel is shown in figure 10-6. It has meters and indicators for the GG section of the engine. Figure 10-8 is an enlarged view of this section. The AIR INTAKE LOW PRESSURE alarm (A) is used to indicate when the differential pressure exceeds 7.5 in. H_2O. This is measured between the ambient air and the combustion air intake, downstream from the moisture separator. The PRESSURE RATIO meter (B) monitors, over a long period of time, the condition of the GG. The input of this meter comes from computations between the P_{t2} and $P_{t5.4}$.

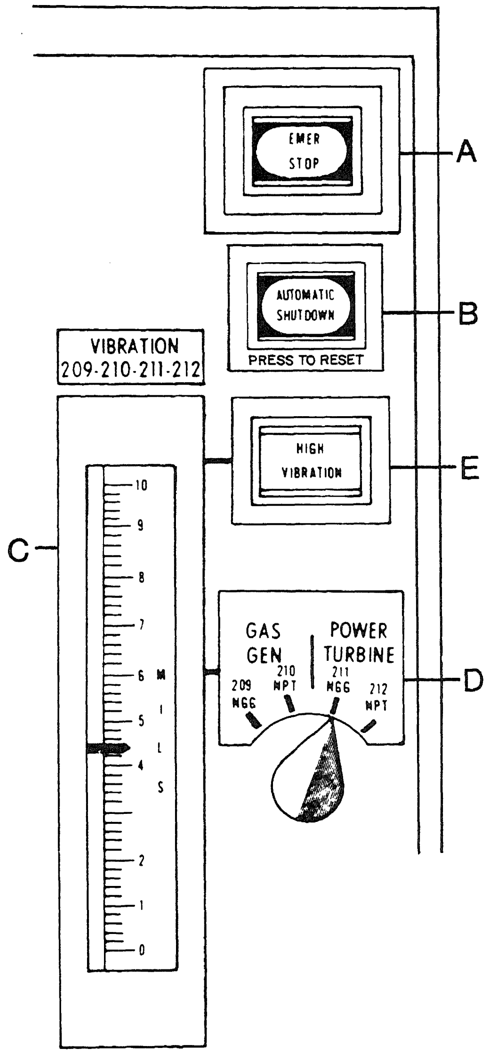
The GG SPEED meter (C) displays the speed of the GG. Associated with this meter is the OVERSPEED alarm (D) which has a set point of 9700 ± 100 rpm. Below the OVERSPEED indicator are the controls and indicators for the bleed air valve. The OPEN/CLOSED indicator (E) displays the actual position of the valve. The OPEN/CLOSE pushbutton control (F) is used to open and close the valve.

EMERGENCY STOP AND VIBRATION.—The locating of the EMERGENCY STOP and VIBRATION section (E) on the engine 1B panel is shown in figure 10-6. Figure 10-9 is an enlarged view of this section.



293.121

Figure 10-8.—Gas generator section of the engine panel.



293.122

Figure 10-9.—Emergency stop and vibration section.

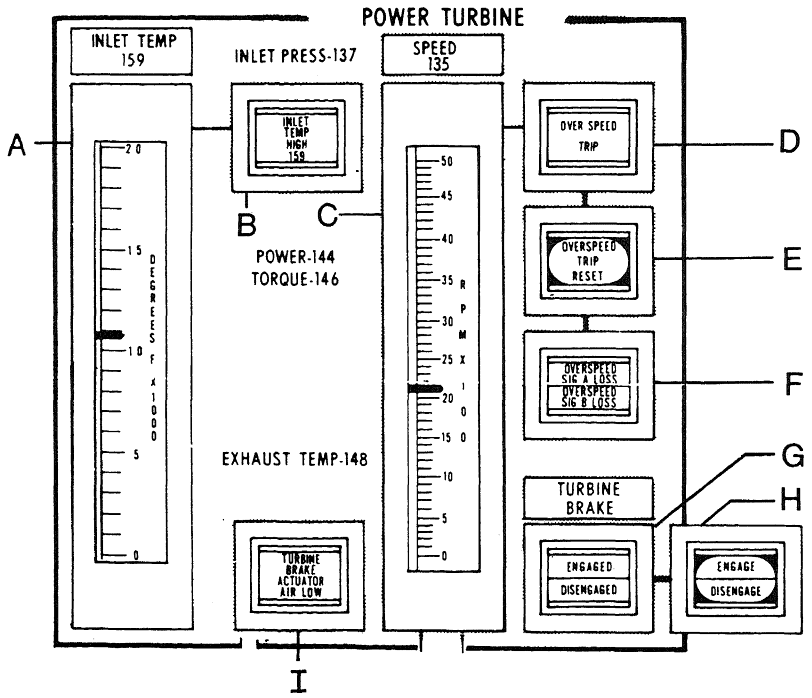
Emergency Stop Switch/Indicator.—The EMER STOP switch/indicator (A) can be initiated by the operator at any time and in any control mode. Depressing the EMER STOP indicator switch on the PCC causes the circuitry in the LOP and the FSEE to immediately de-energize the PT overspeed trip switch. This causes both automatic fuel shutdown valves to close which causes the engine to shut down.

Automatic Shutdown Switch/Indicator.—The AUTOMATIC SHUTDOWN switch/indicator (B) indicates that an automatic shutdown has occurred. This switch resets the automatic shutdown electronics. The PCS initiates automatic shutdown for the following parameters after a GTE is running and provides indication of each shutdown on the PCC.

1. $T_{5.4}$ above 1530°F
2. GT engine oil pressure below 6 psig
3. GT high vibration (GG above 7 mils or PT above 10 mils)
4. Flameout ($T_{5.4}$ less than 400°F after PT fuel manifold pressure becomes greater than 50 psi and after an engine run signal is obtained)

Vibration.—This section has a meter, switch, and an indicator. The meter (C) is always reading the vibration on the engine at the position selected by the switch. The switch (D) is a four-position switch. It allows you to look at the two different vibration pickups. One is located on the GG and the other is on the PT. Each pickup senses both GG and PT vibration. A tracking filter for each pickup separates GG vibration from PT vibration depending on vibration frequency. Limits apply to frequency and not pickup location. The HIGH VIBRATION indicator (E) will illuminate when the vibration on the GG reaches 4 mils and the PT reaches 7 mils. An automatic shutdown occurs when GG vibration reaches 7 mils and PT vibration reaches 10 mils.

FLAMEOUT.—The FLAMEOUT indicator (figure 10-6, item F) will illuminate when $T_{5.4}$



293.123

Figure 10-10.—Power turbine section of the engine.

lrops below 400°F after the fuel manifold ›ressure becomes greater than 50 psi and after an ngine run signal is obtained. When this happens, n automatic shutdown will ensue.

POWER TURBINE.—The location of the PT ection (G) on the engine 1B panel is shown in igure 10-6. Figure 10-10 is an enlarged view of his section. The PT section monitors the operaion of the PT. It has two meters, two pushuttons, and five indicators.

The first meter is the INLET TEMP ($T_{5.4}$) neter (A). It displays the temperature of the gas ntering the PT. Associated with this meter is the NLET TEMP HIGH alarm indicator (B) for high $T_{5.4}$. It has an alarm set point of 1500°F. An utomatic shutdown will occur if $T_{5.4}$ reaches 530°F and battle override is not on.

The second meter, the PT SPEED meter (C), hows the speed of the PT. The meter is fed from wo sensors mounted on the rear frame of the urbines that sense PT speed.

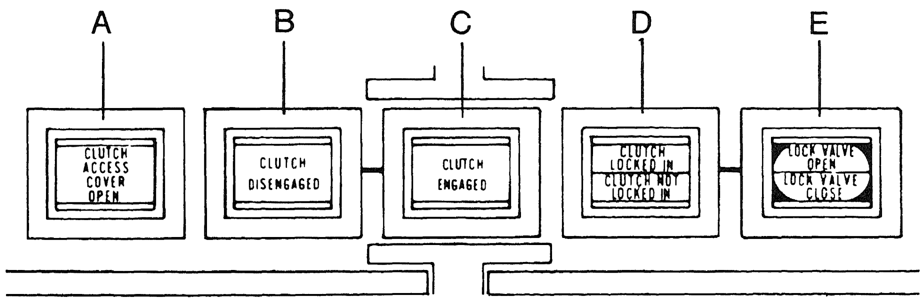
To the right of this meter is an OVERSPEED TRIP indicator (D). It illuminates if either of the sensors senses a PT speed greater than 3960 ± 40 rpms. This condition causes the engine o shut down because the fuel shutdown valves re de-energized.

Directly below this indicator is the OVER-SPEED TRIP RESET pushbutton (E). It is used o reset the overspeed trip and to latch the fuel 'alves during starting. Next is a split-legend ndicator (F) which is labeled OVERSPEED SIGNAL A LOSS/OVERSPEED SIGNAL B LOSS. These indicators will illuminate when the PT speed drops below 100 rpms or a malfunction in the circuit occurs. When the PT speed becomes less than the loss of signal setting on both speed signal input channels or greater than the overspeed setting on either speed signal input channel, the fuel shutdown valves de-energize (the engine will shut down). If the PT speed loss signal occurs on only one channel, the engine will continue to run.

The bottom part of this section is used to control and monitor the operation of the turbine brake. The turbine brake indicator (G) displays the actual status of the brake, either ENGAGED or DISENGAGED. The split indicator next to it is used to control the brake. Depressing it will either ENGAGE or DISENGAGE the brake assembly. The TURBINE BRAKE ACTUATOR AIR LOW indicator (I) will display when the air pressure to the brake actuator is too low. It illuminates when brake air pressure is less than 70 psi. The turbine brake may not be engaged unless the PT speed is below 250 rpm and the engine fuel manifold pressure is below 50 psig.

CLUTCH.—The location of the clutch section (H) on the engine 1B panel is shown on figure 10-6. Figure 10-11 is an enlarged view of this section. The clutches on this class ship are synchronized self-shifting. The only operation action required to engage and disengage them is the removal of the brake and operation of the throttle.

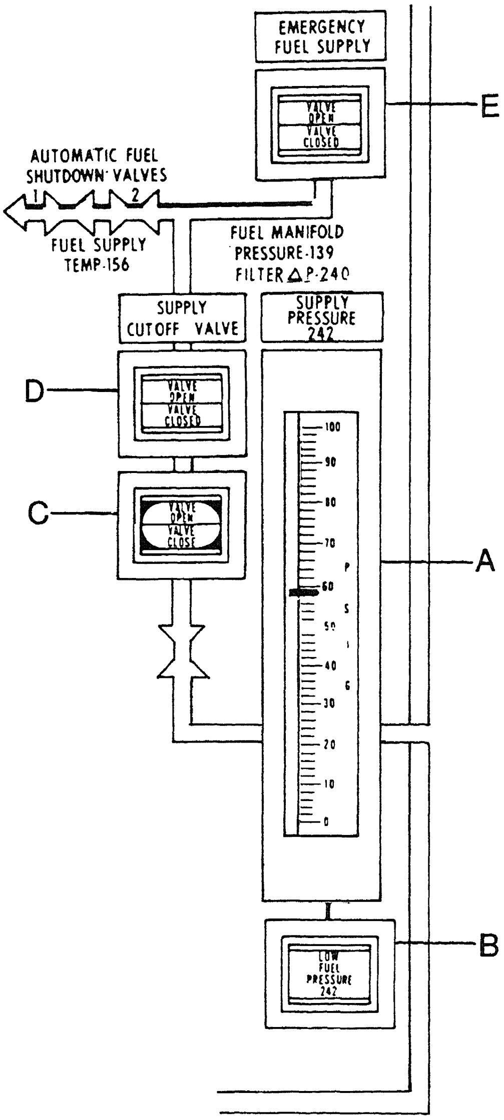
This section of the panel has four indicators and one pushbutton. The first indicator (A) in the section is CLUTCH ACCESS COVER OPEN. This indicates that the access door to the clutch is open. The next two indicators (B and C) display the clutch status, either CLUTCH



293.124

Figure 10-11.—Clutch section of the engine panel.

DISENGAGED or CLUTCH ENGAGED. The CLUTCH LOCKED IN/CLUTCH NOT LOCKED IN indicator (D) displays the status of the lock-in/lock-out mechanism of the clutch. Locking out the clutch provides for operation of the GT without turning the MRG. For normal operation the clutch must be locked in. The last control (E) is a pushbutton no longer in use. Previously, it was used to operate the lock valve.



293.125

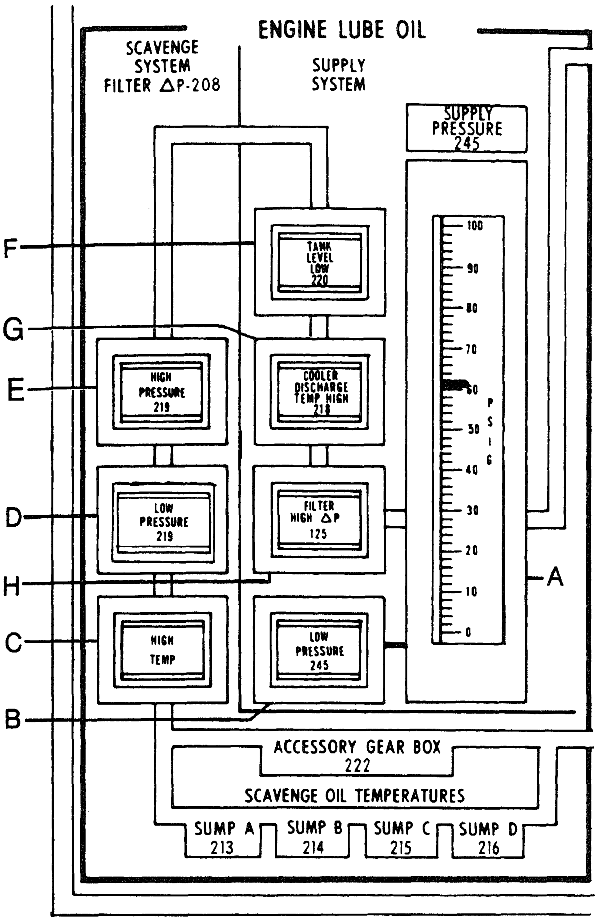
Figure 10-12.—Engine fuel supply section of the engine panel.

ENGINE FUEL SUPPLY.—The location of the engine fuel supply section (I) on the engine 1B panel is shown on figure 10-6. Figure 10-12 is an enlarged view of this section. It has the control and monitor components used to operate the fuel supply to the engine.

The SUPPLY PRESSURE meter (A) displays the pressure of the fuel from the fuel service system to the engine. Associated with this meter is the LOW FUEL PRESSURE alarm (B) which sounds at 8 psi. Fuel supply pressure is sensed after the fuel supply cutoff valve. The PCC has an indicator and control for this valve. The VALVE OPEN/VALVE CLOSE pushbutton (C) is used to control the valve. Above it is the VALVE OPEN/VALVE CLOSED split indicator (D). It monitors the actual position of the valve, either open or closed. The VALVE OPEN/VALVE CLOSED indicator (E) is the last indicator. It also monitors valve status of the emergency JP-5 supply valve. This valve is held closed electrically. Upon loss of power to the normal fuel service system, the valve will open. This allows the GTs to run on JP-5 from a 350-gallon head tank.

ENGINE LUBE OIL.—The location of the engine lube oil section (J) of the engine 1B panel is shown on figure 10-6. Figure 10-13 is an enlarged view of this section. This section monitors the operation of the engine's lube oil supply and scavenge systems.

No control features are used in this section. It is only a monitor panel. It has a meter and seven indicators used to detect abnormal conditions of the lube oil system. The meter (A) displays the supply pressure of the lube oil. Associated with the meter is the LOW PRESSURE alarm indicator (B). This alarm sounds when the lube oil pressure drops to 15 psig. (Remember, an auto shutdown will occur if lube oil pressure drops to 6 psig.) The third component is the scavenge HIGH TEMP alarm indicator (C). This is a summary-type alarm that sounds when any of the five RTDs detect a temperature above 300 °F. When this alarm sounds, the operator should use one of the digital displays to identify which scavenge temperature is high. The scavenge LOW PRESSURE alarm (D) activates when scavenge pressure drops below 5 psig; the HIGH



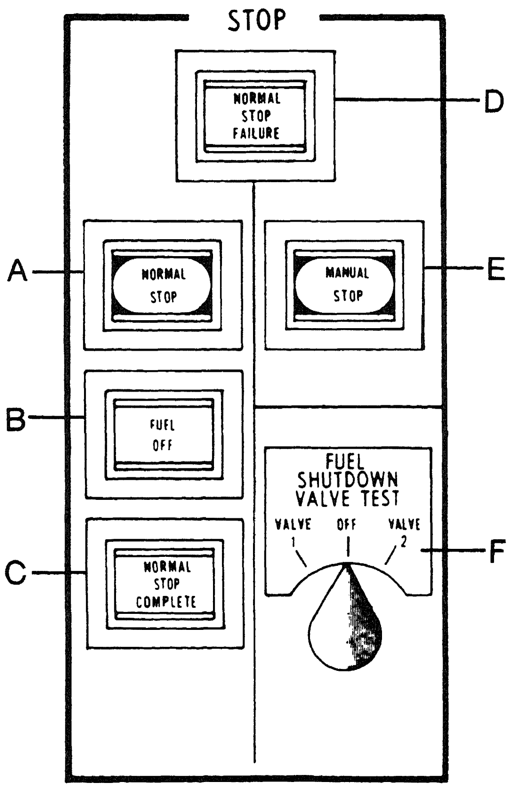
293.126
Figure 10-13.—Engine lube oil section of the engine panel.

PRESSURE alarm (E) sounds when scavenge pressure is above 130 psig.

The TANK LEVEL LOW indicator (F) is used to monitor the level of the LOSCA lube oil tank. The alarm sounds when the tank level falls to 9.6 gallons. The COOLER DISCHARGE TEMP HIGH alarm (G) monitors the outlet temp of the oil leaving the LOSCA cooler. If the temperature of the oil exceeds 250 °F, this alarm will sound. The last indicator is the FILTER HIGH ΔP alarm (H). This alarm activates when the differential pressure across the lube oil supply filter exceeds 20 psid.

STOP.—The location of the stop section of the engine 1B panel is shown on figure 10-6. It is located above the lube oil section on the engine panel. Figure 10-14 is an enlarged view of this section.

The controls on the stop section are used to perform normal and manual stops. This section has three indicators, two pushbuttons, and a switch used for engine stopping. The first control, the NORMAL STOP pushbutton (A), is used to initiate a stop using the start/stop sequencer in the FSEE. This sequence, upon initiation, allows the engine to run at idle for 5 minutes. After 5 minutes it de-energizes the fuel shutdown valves causing the engine to shut down. This sequence may only be initiated if the engine is at idle. By advancing the throttle above idle, you can interrupt the normal shutdown any time before the fuel valve closure. The FUEL OFF indicator (B) is illuminated any time fuel manifold pressure is below 50 psi. The NORMAL STOP COMPLETE indicator (C), when illuminated, indicates $T_{5.4}$ is below 400 °F and fuel manifold pressure



293.127
Figure 10-14.—Stop section of the engine panel.

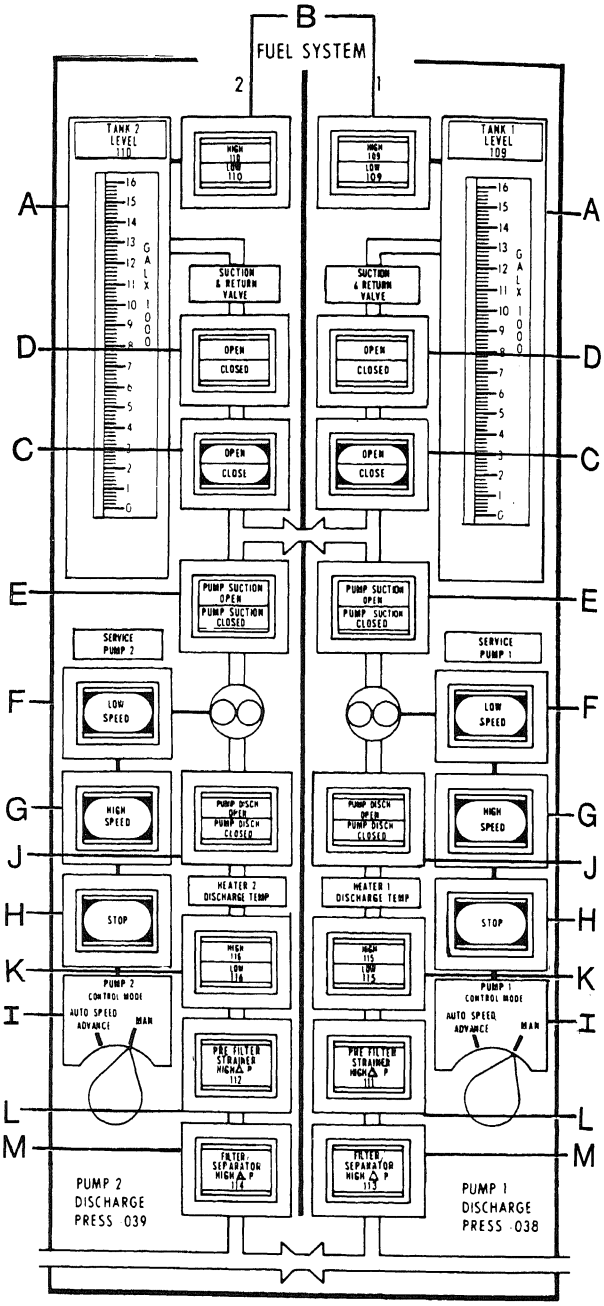
is less than 50 psi within 90 seconds after the completion of the 5-minute cooldown timer. Associated with this indicator is the NORMAL STOP FAILURE alarm (D). This indicator illuminates if, 90 seconds after the completion of the 5-minute cooldown timer, $T_{5.4}$ is above 400 °F or fuel manifold pressure is above 50 psig.

The other pushbutton in this section is the MANUAL STOP pushbutton (E). When it is depressed, the fuel shutdown valves are de-energized causing the engine to immediately stop. This stop should only be done after the engine has been allowed to cool down for 5 minutes to prevent engine damage. The three-position switch located below the MANUAL STOP pushbutton is the FUEL SHUTDOWN VALVE TEST switch (F). This switch is spring-loaded to the OFF position. Moving the switch to either the valve 1 or valve 2 position will shut the corresponding fuel shutdown valve and should stop the engine if the valve is operating properly. This is used to test the integrity of each of the fuel shutdown valves. Before moving this switch back to the OFF position, following PMS, depress the MANUAL STOP pushbutton to lock out both fuel valves. (NOTE: Remember to use the EOSS when doing any operation from the PCC.)

Fuel Oil Service System Panel

Located between the two engine panels is the fuel oil service system panel (figure 10-15). The panel is divided into two sections labeled 1 and 2. Each section has identical controls and indicators used to operate the fuel system on either number 1 or 2 tank, pump, heater, prefilter, or filter/separator. One tank and pump combination can supply both engines.

The level of a service tank may be monitored using the TANK LEVEL meter (A). Associated with this meter is a HIGH/LOW alarm (B) used to alert the operator when a tank is either full or needs refilling. The fuel oil tank suction and return valves may be operated from this panel by an OPEN/CLOSE pushbutton (C). The OPEN/CLOSED indicator (D) shows the status of both valves. This determines the tank that is supplying fuel to the fuel pump and where the excess fuel is returned. The valves may be opened and closed using the OPEN/CLOSE pushbutton (C). The pump suction valves (one per



293.128

Figure 10-15.—Fuel oil service system panel.

pump) are electrically interlocked with the pump start/stop pushbuttons and opened before the pump starts. Indication is provided at the PCC by the PUMP SUCTION OPEN/PUMP SUCTION CLOSED indicator (E).

Three pushbuttons and a control mode switch control the two service pumps. The three pushbuttons are labeled LOW SPEED (F), HIGH SPEED (G), and STOP (H). The CONTROL MODE switch (I) is used to set the pumps in the MAN (manual) mode or the AUTO SPEED ADVANCE mode. Each pump is a two-speed pump. In the manual mode the operator selects the speed of the pump (low or high) by depressing the proper pushbutton. In the automatic mode, a drop in fuel pressure will shift the pump from low to high. If low speed is again desired, the operator must shift the speed back to low. The pump discharge valve is equipped with a limit switch to show the actual position of the valves. This valve is operated manually at the valve.

The HEATER DISCHARGE TEMP HIGH/LOW alarm (K) is a split indicator alarm for high or low temperature. If the temperature of the fuel leaving the heater exceeds 110 °F, the high alarm sounds. Likewise, if the temperature drops below 60 °F, the low alarm sounds.

A fuel prefilter is used in the system to remove large particulate matter. If its ΔP exceeds 10 psid, the PREFILTER STRAINER HIGH ΔP alarm (L) activates. A second filter, called the FILTER/SEPARATOR, is used to separate out smaller particles and water. If this becomes clogged with a ΔP of 12 psid, the FILTER/SEPARATOR HIGH ΔP alarm (M) activates.

Gear Lube Oil Panel

The gear lube oil panel (figure 10-16) is used to control and monitor the flow of lube oil to the MRG.

The first indicator (A), SUMP LEVEL LOW, alerts the operator when the level of the MRG oil sump drops below 870 gallons. The indicator next to that is the STRAINER HIGH ΔP alarm (B). If the differential pressure across the lube oil strainer (actually mounted in the line after the pumps) exceeds 12 psid, this alarm activates.

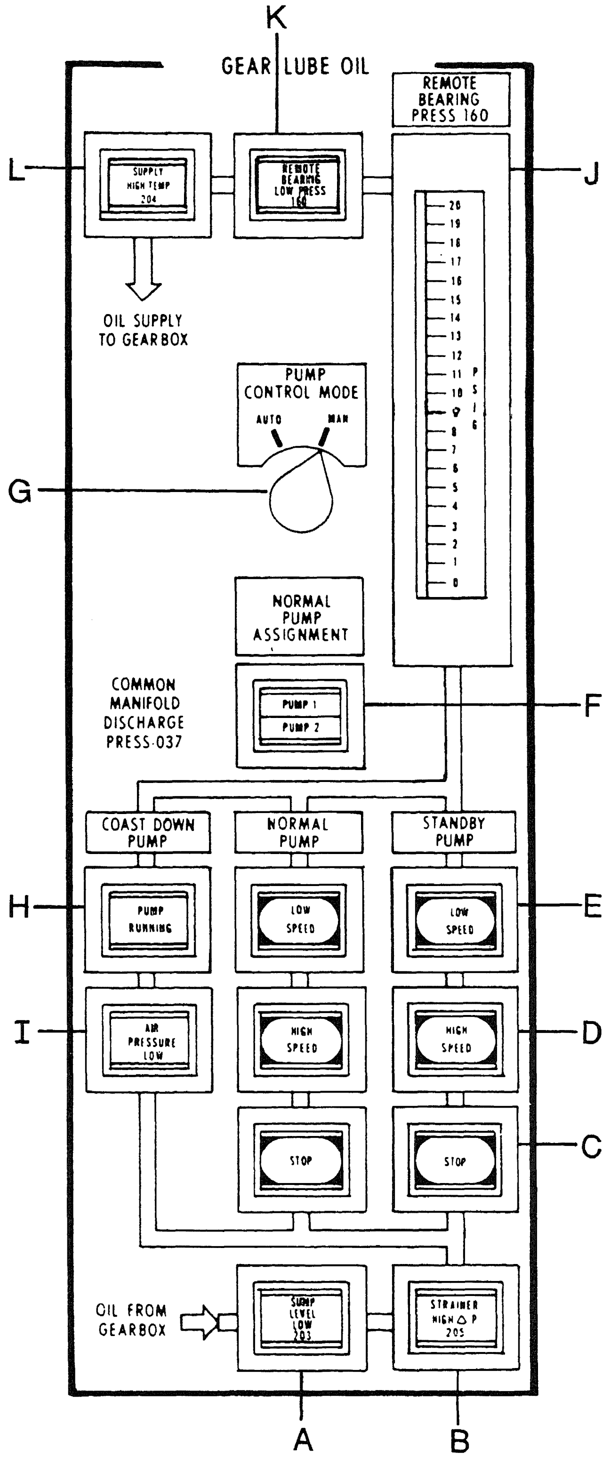


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Figure 10-16.—Gear lube oil panel.

Gear lube oil pump control is available from the PCC for the two motor-driven two-speed pumps. The pumps may be operated in either the manual or automatic mode. Normal and standby pump assignment is done by a switch on the lube oil pump controller in the engine room.

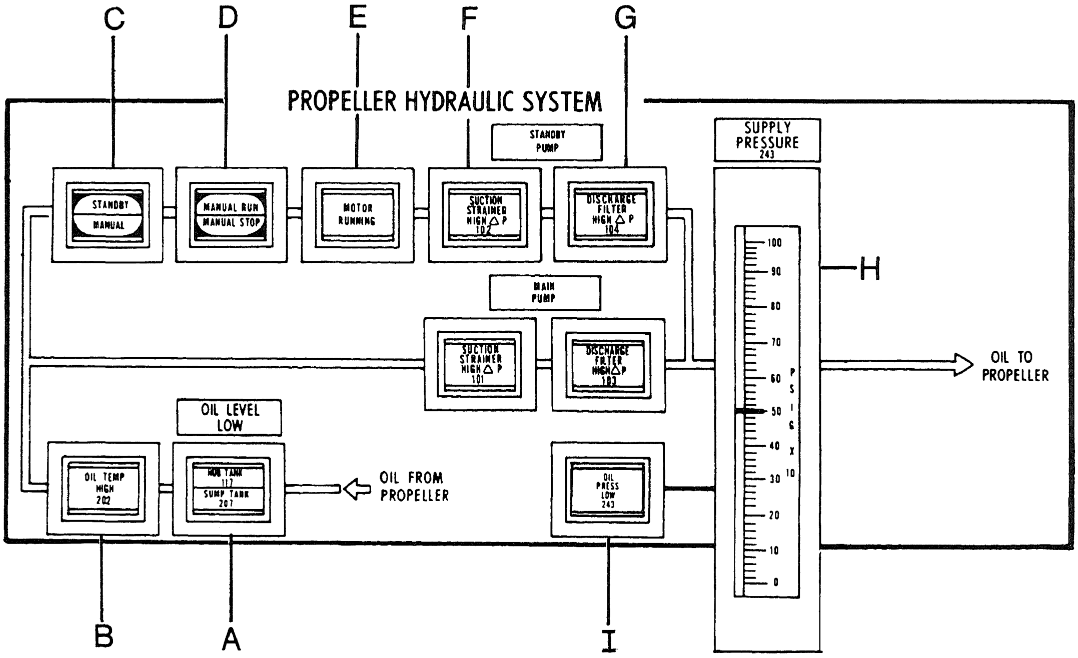
The speed control pushbuttons are used for manual speed control. The operator may use these pushbuttons in the manual mode to STOP (C), run in HIGH SPEED (D), or run in LOW SPEED (E) the two lube oil pumps. First the normal pump is selected (its selection is shown by the NORMAL PUMP ASSIGNMENT PUMP 1/PUMP 2 indicator (F)). Then the operator manually starts the selected pump to start the lube oil system. After the lube oil system is started, the operator may put the system in automatic by placing the PUMP CONTROL MODE switch (G) to AUTO. In the automatic mode, the pumps cycle up in speed in response to pressure decreases. If the pressure drops to 15 psig, the normal pump shifts from low to high speed. A drop in pressure to 13 psig causes the standby pump to start in low speed. A further decrease in pressure to 11 psig causes the standby pump to go to fast. When system pressure returns, the pumps must be manually cycled to lower speeds or off.

If the lube oil pressure drops to 9 psig, or if both electric pumps lose power, a third air-driven pump provides oil to the MRG. This pump is called a coastdown pump. It has a PUMP RUNNING indicator (H) on the PCC to show when it is running. The coastdown pump will only run if the shaft is turning. Also, it will stop if the lube oil pressure exceeds 15 psig. Another indicator, the AIR PRESSURE LOW indicator (I), alerts the operator when the air supply to the pump is low. It activates at 2700 psig.

The lube oil pressure is monitored at the PCC by monitoring the hydraulically most remote bearing pressure on the REMOTE BEARING PRESS meter (J). If the remote bearing pressure drops to 9 psig, the REMOTE BEARING LOW PRESS alarm indicator (K) activates. The lube oil temperature is also monitored. If it exceeds 130 °F, the SUPPLY HIGH TEMP alarm (L) sounds.

Propulsion Control Panel

The propulsion control panel (figure 10-17) is shown as a foldout at the end of this chapter. It



293.131

Figure 10-18.—Propeller hydraulic system section of the propulsion control panel.

is one of the bottom panels of the PCC. This panel has the controls and indicators for the propeller hydraulic system, shaft speed and propeller pitch, MRG monitoring, and control transfer.

PROPELLER HYDRAULIC SYSTEM.—This section of the propulsion control panel has a meter, eight indicators, and two control pushbuttons. These are used to operate the hydraulic system of the controllable pitch propeller. Figure 10-18 is an enlarged view of this section.

The HUB TANK/SUMP TANK split indicator (A) monitors the oil level of the sump and head tanks. If the level in the head tank falls to 35 gallons, the HUB TANK indicator illuminates. If the sump tank level drops below 425 gallons, the SUMP TANK indicator illuminates. The next indicator (B), OIL TEMP HIGH, activates to alert the operator that the oil temperature in the system has exceeded 160°F.

Normally, the hydraulic pressure is supplied to the system by the pump that is driven by the reduction gear (attached gear pump). When this pump cannot provide the proper pressure, it must be augmented by the standby motor-driven pump. Two control pushbuttons are used to operate the motor-driven pump. The STANDBY/MANUAL pushbutton (C) sets the mode of operation. In the standby mode, when the shaft speed drops to about 105 SRPM, the motor-driven pump starts. When the pushbutton is placed in the manual mode, the motor-driven pump must be started by the operator. The operator uses the MANUAL RUN/MANUAL STOP pushbutton (D). When the motor-driven pump is running, the MOTOR RUNNING indicator (E) illuminates. Both pumps have suction strainers in the pump suction lines and discharge filters in the pump discharge lines.

This section of the panel has indicators to alert the operator when the discharge filters and the suction strainers become clogged. If the differential pressures of the suction strainers reach 7 in. Hg, the SUCTION STRAINER HIGH ΔP alarm (F) activates. If the discharge filter ΔP exceeds 40 psid, the DISCHARGE FILTER HIGH ΔP alarm (G) activates. A meter (H) monitors the CPP hydraulic supply pressure. Associated with this meter is the OIL PRESS LOW indicator (I). If supply oil pressure drops to 40 psig, this alarm sounds.

ENGINE ORDER TELEGRAPH.—Located below the propeller hydraulic section, is the EOT (figure 10-19). This is used to relay engine orders from the bridge to the PCC. When the bridge orders a change of speed, one of the pointers in the EOT will point to the requested speed. The PCC operator, to acknowledge the order, moves the other pointer to match the bridge pointer. This is done using the knob (A) below the EOT. If the pitch of the propeller and the EOT indicate opposite directions (ahead and astern), the EOT WRONG DIRECTION alarm bell (B) sounds.

SHAFT PERFORMANCE MONITORING.—Located to the right of the propeller hydraulic system panel are the indicators used to monitor the propeller shaft performance. This

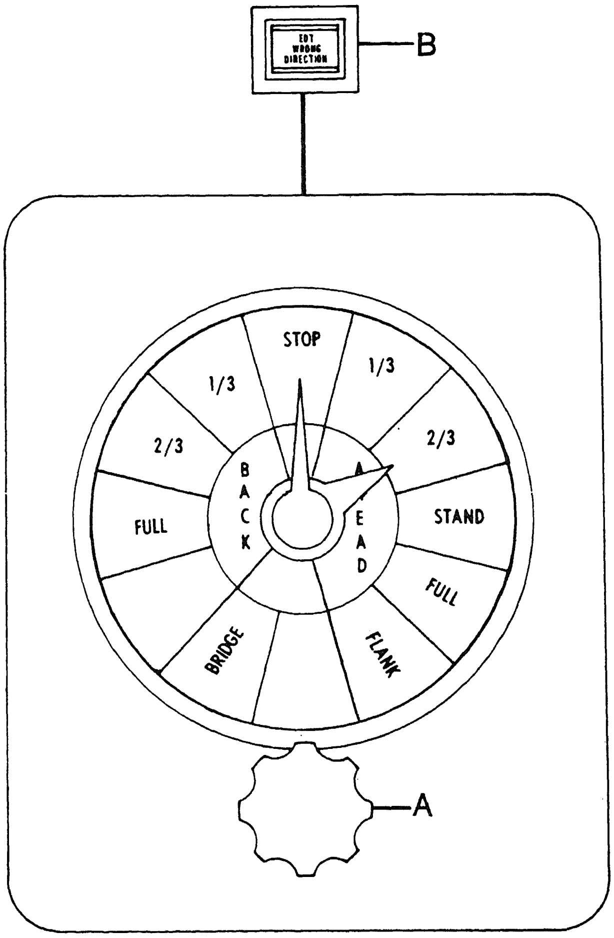


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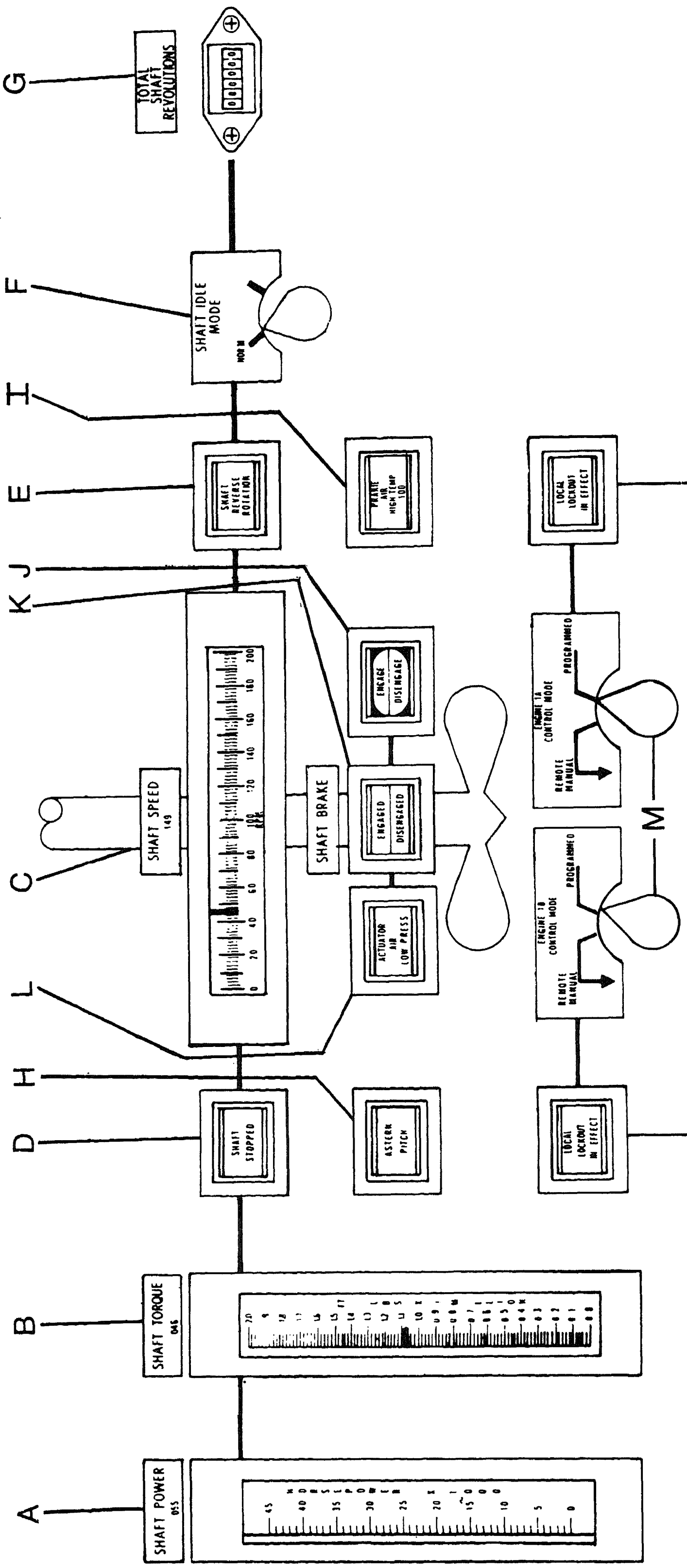
Figure 10-19.—Engine order telegraph.



293.133

Figure 10-20.—Shaft performance monitoring section.

section (figure 10-20) has three meters used to monitor shaft speed, torque, and horsepower; shafting indicators; shaft brake controls; and indicators and engine mode select controls.

The SHAFT POWER meter (A) displays shaft power. It displays in horsepower and receives its input from the processor. The next meter (B) is used to display SHAFT TORQUE. This parameter is also sent from the processor and displays in ft-lb. The third meter (C) is a horizontal edgewise meter that shows SHAFT SPEED. Associated with the shaft speed meter is the SHAFT STOPPED indicator (D). When illuminated, this indicator shows shaft stopped when it is rotating less than 1/5 rpm. On the other side of the shaft speed meter is the SHAFT REVERSE ROTATION indicator (E). When this indicator is illuminated, the propeller shaft is rotating in the reverse direction. Next to this indicator is the SHAFT IDLE MODE switch (F). This switch has only one position (NORM). It is not used. To the right of the switch is the TOTAL SHAFT REVOLUTIONS counter (G). This counter shows total shaft revolutions of the propeller.

The ASTERN PITCH indicator (H) shows when the pitch of the propeller is in the astern direction. The PRAIRIE AIR HIGH TEMP indicator (I) is an alarm indicator that activates when prairie air temperature exceeds 135°F.

The shaft brake section is located below the shaft speed meter. One control pushbutton and two indicators are used to display conditions of the shaft brake. The shaft brake ENGAGE/DISENGAGE pushbutton (J) is used to apply and release the shaft brake. It may only be applied if the following conditions are met.

- Shaft speed is less than 75 rpm.
- Throttles are at idle.
- Pitch is at zero.
- Only station in control of the engine(s) may apply shaft brake.

When these permissives are met, the control pushbutton activates the shaft brake. If one of these permissives is lost, the shaft brake will release. The shaft brake indicator (K) will show the actual status of the shaft brake, either ENGAGED or DISENGAGED. The shaft brake ACTUATOR AIR LOW PRESS alarm indicator (L) alerts the operator if the air pressure used to operate the shaft brake drops below 1150 psig.

Below the shaft brake section are two engine control mode rotary switches (M), one per engine. These switches are used to place the engines in either PROGRAMMED or REMOTE MANUAL mode. The remote manual mode is used when starting or stopping a GT. It is also an alternate method of operating the throttle/pitch combination. Programmed control is the normal operating throttle mode used after the engine is started. These modes are discussed later in this chapter when we cover the throttle controls.

MODE SETTING AND REDUCTION GEAR MONITORING.—To the right of the shaft performance section is the area of the propulsion control panel used to set propulsion modes, programmed control location, and to monitor the reduction gear bearings. This area is shown in figure 10-21.

The first control (A) is used only in programmed mode and is labeled PROPULSION MODE. This control has two positions, POWER and SPEED. When placed in the POWER position, the processor automatically adjusts the pitch and PLA commands to provide a consistent load on the engine. To do this, the processor uses the torque computer. At powers above full pitch, an almost linear relationship between the position of the programmed control lever and steady state shaft rpm exists. In the power mode, the engine or engines are kept at a steady power level. In some sea states and/or under some maneuvering conditions, the shaft rpm will vary above or below a normal value. This variation in the power mode is normal and expected.

The other position of the switch is the SPEED mode. When operating in the speed mode, the processor automatically adjusts the propeller pitch signals and the PLA actuator signals to provide a constant propeller shaft rpm. To do this, the processor uses built-in power schedules and propeller shaft rpm feedback. The programmed control lever gives the operator fine control of shaft rpm. The operator can make careful adjustments to ship's speed in relatively calm seas and during alongside evolutions.

Just to the right of the propulsion mode switch is the ROUGH WEATHER DAMPING switch (B). This is an ON/OFF switch. This switch is only

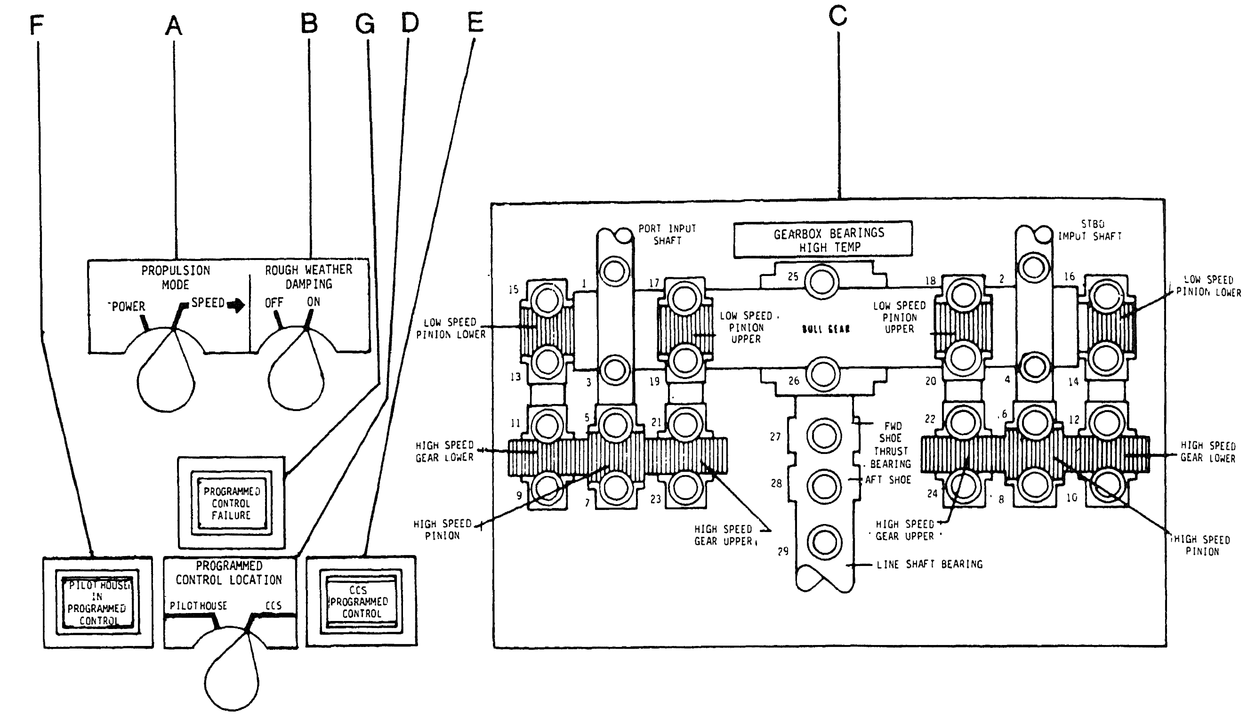


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Figure 10-21.—Mode setting and reduction gear monitoring section.

operative when operating in programmed control mode and in the speed mode. When the rough weather damping circuit is used, the processor attempts to even out PLA actuator command signals during rough sea conditions. This is to reduce hunting (fluctation) of the propeller shaft rpm.

The next section has the reduction gear bearing high temperature indicators (C). There are 29 indicators, one for each bearing in the MRG. Associated with each indicator is a number, 1 to 29; placing zeros in front of these numbers makes three-digit numbers. You will then have the DDI number for that bearing. If you use these numbers as reference numbers, 1 to 26 are for the babbitt bearings; the sensors are in the babbitt and are sensing babbitt temperature. Numbers 27 and 28 are for the thrust bearings; number 29 is for the line shaft bearing.

Below the propulsion mode and rough weather damping switches is a two-position PROGRAMMED CONTROL LOCATION switch (D). It determines the location of the programmed control. The programmed control location rotary switch, when positioned to CCS, shows that the control of the programmed mode is at the PCC. The other switch position is PILOTHOUSE. With the switch in this position, control of programmed control is at the pilothouse (SCC).

Associated with these switches are three indicators. On the right-hand side is the CCS PROGRAMMED CONTROL indicator (E). When this indicator is illuminated, the control of the propulsion system is at the PCC. On the left side of the switch is the PILOTHOUSE IN PROGRAMMED CONTROL indicator (F). When this indicator is illuminated, the control of the propulsion system is at the pilothouse. Directly above this switch is the PROGRAMMED CONTROL FAILURE indicator (G). This indicator illuminates when the processor has failed or has not made a complete cycle and has stopped. If this occurs, the processor will have to be restarted. During this time period, the DDIs and the loggers may not be operating properly.

SHAFT CONTROL.—The lower section of the propulsion control panel (figure 10-22) has

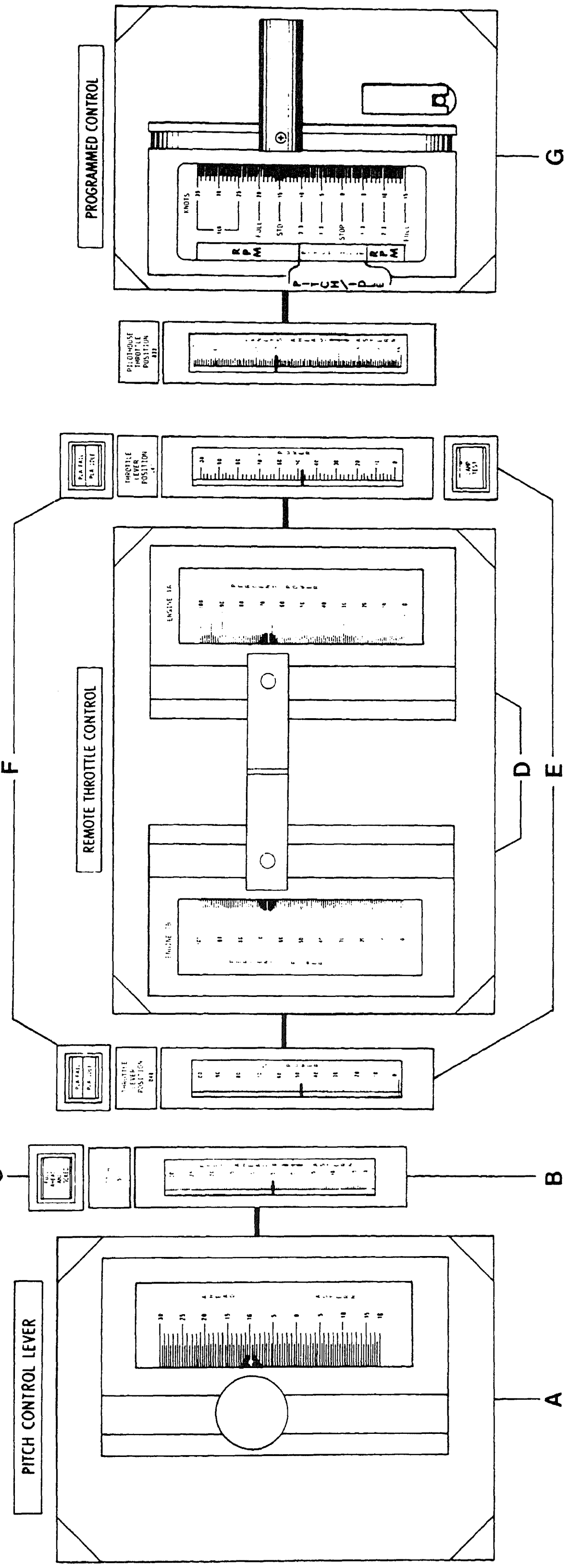

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Figure 10-22.—Shaft control.

the levers and indicators used to operate and monitor the speed and pitch of the propeller shaft.

The lever at the left is the PITCH CONTROL LEVER (A). It controls propeller pitch in the remote manual mode. To the right of this lever is the PITCH meter (B). It shows the actual pitch position. Above this meter is the FULL AHEAD AND LOCKED indicator (C). This indicator illuminates when the pitch of the propeller is full ahead and mechanically locked.

The next two levers (D) are for controlling the speed of the GGs, one lever for each GG. These levers can be locked together so that when the engines operate together, their speed will be the same. On either side of the REMOTE THROTTLE CONTROL levers are meters for the THROTTLE LEVER POSITION (E), one for each engine. The meters are always showing the position of the throttle in percentage of power. This is regardless of how the engine or engines are being controlled. Above each meter is a split-legend indicator (F). The upper half reads PLA FAIL, the lower half reads PLA IDLE. When the PLA IDLE indicator illuminates, the throttles are setting at the idle position; the idle position is 13 degrees of PLA. When the PLA FAIL indicator illuminates, the throttle is at some position less than 13 degrees of PLA.

The last lever to the right is the PROGRAMMED CONTROL lever (G). This lever is only functional when the engine control mode switch of either engine is in the PROGRAMMED position. The programmed control mode is the primary mode of operation. The propulsion system can be operated in the programmed control mode using either one or both GTEs.

The programmed control lever, through the processor, controls the propeller blade pitch and the speed of one or both GTEs. The operator positions the programmed control lever. Then the processor senses the position of the programmed control lever. It computes the correct propeller blade pitch command signals and correct PLA actuator command signals. The propeller blade pitch command signals, developed by the processor, are transmitted to the electrohydraulic servo valve to position the pitch of the propeller blade. The PLA actuator command signals, developed by the processor, are transmitted to the FSEE for control of the engines. With one or both engines at idle, the propeller blade pitch at zero, and the shaft rotating, there is neither ahead nor astern thrust to the ship. Pushing the programmed control lever forward (away from the operator) changes the propeller blade pitch; this causes the ship to move forward. Pulling the programmed control lever back from the zero position (toward the operator) reverses the propeller blade pitch; this causes the ship to move astern. Changing the propeller blade pitch from zero puts a load on the propeller shaft, the reduction gear, and the PT(s).

As the propeller blade pitch increases, the processor automatically adjusts the fuel flow to the GG. This is to maintain the propeller shaft rpm as required by either the power mode or the speed mode. Once full propeller blade pitch is achieved, further advances to the programmed control lever increase propeller shaft rpm. To decrease the ship's speed, the operator moves the programmed control lever back toward the zero position; this reduces propeller shaft rpm and then propeller blade pitch.

CAUTION

> The programmed control mode must not be used when the propeller blade pitch is being controlled from the oil injection box or when it has been locked in the full-ahead position. This is because no input has been made to the processor that the propeller blade pitch is being operated manually or has been locked in the full-ahead position; the processor would still be computing and transmitting propeller blade pitch commands.

Fuse Panels

The fuse panel (figure 10-23) is located just to the left of engine start panel 1B. This panel has fuses for the seawater cooling, fuel system, gear lube oil, propeller hydraulic pump, and for transducers-24 VDC. When a generated command does not appear to be received, troubleshooters should begin by checking the associated fuses. The only time voltage is applied across the fuse is when a command is transmitted.